HANDBOOK OF FORECASTING TECHNIQUES

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Prepared for:

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The report is designed to help planners in the Army Corps of Engineers improve their expertise in long range forecasting. Twelve basic methods suitable for a wide range of technological, economic, social, and environmental forecasting are selected and discussed. Procedures for using each method are described and illustrated with examples. Some 150 forecasting techniques are listed in the appendix.

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CONTENTS

APPENDICES

ILLUSTRATIONS

TABLES

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This Handbook, initially proposed by Dr. G. P. Johnson (then employed at the Institute for Water Resources) has been prepared under the administrative direction of Mr. James Tang of IWR. The project team wishes to acknowledge the constructive guidance provided by Mr. Tang.

Arnold Mitchell, Senior Social Economist at Stanford Research Institute, served as Project Leader. Major contributions to the study were made by Pamela G. Kruzic, Systems Analyst, Peter Schwartz, Policy Analyst, and Benjamin E. Suta, Senior Operations Analyst. Two consultants also contributed significantly to the study. David C. Miller, a well-known futurist, teacher, and principal at DCM Associates of San Francisco, drafted considerable portions of the text. Burnham H. Dodge, who recently retired from the Corps of Engineers following a long and distinguished career, was helpful in advising the project team on Corps concerns and in providing much of the material utilized in the case examples illustrating the forecasting techniques.

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We are indebted to Ruth Miller for preparing the Glossary of Terms and the Index.

Section I

INTRODUCTION

Purpose and Structure of Handbook

In a real sense, planners are among the principal architects of the future. This volume is designed to help planners in the Corps of Engineers Civil Works Program improve their professional expertise in long-range forecasting. The study attempts to combine the breadth of a text with the specificity of a handbook.

The report focuses on 12 basic techniques suitable for a wide range of technological, economic, social, and environmental forecasting. These techniques were selected from a much larger number as being most germane to the spectrum of forecasting problems faced by the Corps. In Section II of this report these 12 techniques are compared along a variety of dimensions. In Sections III, IV, and V each method is described in terms of uses, types of results, time and personnel requirements, costs, and several other characteristics; in addition, instructions are given on procedures for applying each method, along with case illustrations, many drawn from Corps experience. References for further study appear in Section VI. Appendices present supporting information and a glossary of terms; a detailed index to the report is included.

Why Forecast?

It is evident that the activities of the Corps today impact upon numerous aspects of the environment and society and will for generations to come. The Corps is keenly aware of this. As a result, it conducts numerous surveys and investigations each year designed to look ahead and probe the potential future impacts of possible Corps activities. Almost without exception, these studies require forecasts of various sorts as a basis on which to determine the optimum course of action in view of competing interests and concerns. Forecasts, therefore, are an integral and critical component of the Corps planning process.

The explosive concern about the future that has emerged in recent years results from growing awareness of several overlapping problems:

- Natural resources no longer can be considered inexhaustible.
- The environment no longer is impervious to the activities of man.
- The values of people and institutions are at the heart of effective environmental planning and must be taken into account.
- While economic growth is still a central concern, the emphasis is shifting from growth to equilibrium and from quantity to quality.

To plan effectively in terms of such global issues as resources, the environment, values, or quality of life requires at least three kinds of analyses, each of which calls for a distinct kind of forecasting methodology.

Problem Identification and Assessment

Most problems encountered by the Corps today have their roots in past trends. Indeed, it has been said that the most up-to-date of forecasters deal with the world as it was 10 years ago. Future problems have their roots in today's trends. The main approach to identifying and bounding coming problems must be through forecasting the emergence or evolution of present and foreseeable trends and events. Are there or are there not problems inherent in the present as it is expected to unfold into the future? If there are, what are their probable long-term effects and what kinds of actions can be taken to resolve the problems? Problem assessment leads naturally to the next major step in planning.

Consequences of Actions

Here the need is to define the future consequences of possible actions that might be taken in response to the problems uncovered in the identification and assessment step. Our society has become so interconnected that it is increasingly necessary to try to foresee the consequences of an action before taking that action. Not too many generations ago our society was like a feather mattress. Poke your finger in one corner and you would ruffle only a few feathers on that spot. Today, society is more like a waterbed. Poke at one corner and the waves will travel, reflect, and reverberate throughout the whole. This characteristic means that no proposed action can be considered in isolation. Physical, economic, social, and other ramifications all must be examined and ther interactions identified.

Normative (Goal-Oriented) Judgment

The next step is to anticipate whether the consequences of actions taken in response to identified problems are in accord with the values of the people and institutions expected to be affected. The problem here is twofold. First, one must identify not only primary impacts of an action, but secondary and tertiary implications as well. These, often unanticipated, side effects frequently "reach into the home" in a way that first-level effects do not. Second, a sense must be gained of how people will respond to alternative courses of action. What do people really want? What are they willing to give up to solve a given problem? It seems clear that some kind of description of what is considered the desirable goal must precede the laying of realistic plans to get there.

Clusters of Forecasting Techniques

To reflect the foregoing three basic aspects of long-range planning, the forecasting techniques discussed in this study have been grouped into three principal categories:

- Time Series and Projections, which deal principally with methods for trend forecasting essential to identifying and assessing current and potential problems.

- Models and Simulations, which deal principally with methods for gauging interactions among events and hence are essential for measuring the consequences of actions.

- Qualitative and Holistic Methods, which deal principally with methods of forecasting the broad context of the future, including societal alternatives and patterns of values on which normative judgments rest.

Changing Inputs to Planning

The evolution of the foregoing system of planning is worth examining from another perspective--that of changing input requirements. The steadily widening range of factors to consider in devising any plan results largely from the changing societal environment in which planning takes place.

Traditionally, most water resource planning was based on extrapolations of historical data to define "the" future. Usually these extrapolations showed an increasing demand for water supply, flood protection, waterway capacity, and so on, and hence the need for water resource development. Economic benefit-cost analyses of various courses of action generally were applied to select the economically optimum course. This system seemed to work admirably for many years. But here and there, starting in the 1960s, the smooth, established approach suddenly met highly vocal and organized resistance. There are many planners in the Corps today who vividly recall the shock of discovering that the people being planned for had ideas totally different from those of the Corps about what they wanted and needed for the future. Hence public involvement has become a driving force in planning. In various degrees this change has also been encountered by other public agencies.

It was this recognition that led to the swift development and application of "soft" techniques able to generate forecasts in such areas as priorities and values. This Handbook discusses a sampling of such methods, a number of them new. These methods include Delphi, panels, various kinds of public surveys, and studies of life ways and life styles. The need to include behavioral components in planning for the public is well described in the following quote:

> Behavioral demand models, developed in part because of the restrictive nature of trend extrapolation, and in part due to a malaise with traditional long-range forecasting in general, provide a freshness of perspective. In essence, we are saying that the mechanistic approach to modeling and simulation for the purpose of forecasting must give way to a better understanding of human behavior. We must know more about our basic attitudes, needs, and desires to properly plan engineered works.*

The discovery that people disagree vehemently about what is desirable for the future (together with the truth that stated policies often are not the policies of fact) also points to the need for more sophisticated approaches to defining a range of possible futures. Otherwise, no real choices can be made. The point is a profound one because the very concept of alternative futures--rather than "the" future flowing from the past without surprises--suggests the need for a complete or holistic picture of a society. One obviously cannot decide what kind of a future one wants on the basis of one or a few variables, such as community water supply, level of industrialization, or population density. To meet this need to choose among plausible futures seen holistically, a variety of new forecasting techniques have been developed in the past decade.

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*Quoted from "Predicting Demand for Engineered Facilities," by James P. Romualdi. Presented at the July 15-19, 1974, ASCE/EIC/RTAC Transportation Engineering Meeting, held at Montreal, Quebec, Canada.

Those described in this study include scenarios, authority forecasting, morphological analysis of society, and divergence mapping.

Integral to describing total societies (alternative futures) and their evolution over time (scenarios) is societal modeling and simulation. Historically, interactive or feedback models preceded most holistic forecasting, since modeling got its start under government (chiefly military) auspices to resolve a variety of planning allocation issues. The techniques developed for other problems proved helpful for the new issues faced by the Corps by tying together many of the diverse ramifications of a specific action. More specifically, the traditional benefit-cost calculations for, say, flood control, needed to be extended to include much more than flood control in the new planning context. Recreational, wildlife, environmental, and hosts of economic and community effects also had to be considered for each action alternative. So the need to see the fine grain within the broad future prospect represents still another input requirement above and beyond traditional Corps planning. Forecasting techniques pertinent to this kind of analysis constitute Section IV. A variety of methodologies are described.

In summary, roughly 80 percent of the forecasting techniques discussed in this report deal with planning issues that seldom showed up in Corps work--or in any institutional planning, for that matter--10 or 15 years ago. It is this revolution in planning that justified this study and has governed the selection of the forecasting techniques discussed here.

How to Use This Handbook

This Handbook has been structured so as to be serviceable in several ways. The following tabulation indicates some of these.

If you want to:	Start by looking at:
See whether a specific item is covered	Subject index at end of Handbook
Look up the meaning of some term	Glossary in Appendix B
Learn how the methods were selected	First part of Section II
Get a quick idea of how the methods compare in terms of planning tasks, subject areas, qualities of output, and so on	Comparison tables in the latter part of Section II
See what forecasting techniques are suitable for your problem	Comparison tables in Section II; full descriptions in Sections III to V
Get a quick idea of what a forecasting technique is	"Abstracts" of methods in Sections III to V
Understand or compare techniques in terms of definition, assumptions, history, main uses, limits and cautions, product or result, level of detail, level of confidence, communicability results, credibility of results, span of forecast, and resources required	Appropriate subsections of descriptions in Sections III to V
Find out whether you will need help in actually using the technique	"Resources" and "procedures" subsections of descriptions in Sections III to V
Learn about procedures for applying the techniques	"Case Example" subsections of descriptions in Sections III to V
Know more about a method than this Handbook tells you	References cited in Section VI

Section II

SELECTION AND COMPARISON OF FORECASTING TECHNIQUES

Selection of Methods Covered

Identification of Planning Areas

It was envisioned from the start that this Handbook would deal with 10 to 15 forecasting techniques of particular usefulness to Corps planners. The initial problem, hence, was to choose these methods and in so doing determine how they might best be described and illustrated. The task was pursued in several stages.

The work started by identifying significant broad areas of planning concern for the Corps. These broad planning areas included the following:

Water quality	Energy	Institutional change
Water demand	Recreation	Social change
Population trends	Shoreline protection	Urbanization
Land use	Economic trends	Regional patterns
Flood control	Public participation	Ecosystems
Navigation	Fish and wildlife	Technological change
Commodity flows	Wastewater management	Resource trends

The forecasting requirements implicit in planning for these and other areas were considered from several viewpoints. Table 1 shows one of these classifications, this one organized in terms of the prime forecasting needs of a field planner in the Corps.

In addition to having to make forecasts in many planning areas, the Corps has need of forecasts for various periods into the future. Moreover, forecasts may be concerned with national, regional, or local areas. Finally, some forecasts strive to predict what will actually happen while others attempt to define plausible alternatives or people's preferences.

Table 1

SELECTED AREAS OF CORPS FORECASTING CONCERN

1. <u>Project Purposes</u>

   Flood control
   Water supply
   Navigation
   Recreation
   Hydropower
   Shore protection
   Wastewater management

2. <u>Basic Elements</u>

   Hydrology
   Meteorology
   Population trends
   Economic trends
   Social trends
   Technological trends
   Land use
   Infrastructure

3. <u>Study Areas</u>

   a. <u>Impact Assessment</u>
      Environmental
      Social
      Economic

   b. <u>Societal Values/Preferences/Conflicts</u>
      Leisure time
      GNP versus quality of life
      Environment versus energy versus food production
      Valuation of water

   c. <u>Institutional Considerations</u>
      Water policies
      Centralization/decentralization of government controls
      National policies

This brief analysis revealed the extraordinary diversity of Corps forecasting needs, and indicated that the selection of methods to be covered in the Handbook should start from the broadest possible base.

Initial List of 150

A list of 150 techniques mentioned in the forecasting literature was compiled and arrayed under six descriptive headings:

(1) Forecasting via surveys

(2) Barometric or indicator forecasting

(3) Forecasting via trends

(4) Forecasting via models and simulations

(5) Normative forecasting

(6) Forecasting via analogy and creativity techniques

The initial list of forecasting techniques appears as Part I of Appendix A. It was fully recognized from the start that this list contained many overlaps, methods at different levels of generality, and omitted many specialized variations of more basic forecasting techniques; further, the classification of the methods was subject to dispute. Nevertheless, the list served the purpose of providing a useful "universe" from which to start the winnowing process.

The 73

The initial list was easily trimmed to about 100 by eliminating the more obvious and severe overlaps. As a convenience in winnowing further on a systematic basis, a one-page form was devised to describe each method.

Each member of the core project team* was given a batch of the 100 methods and asked to describe them, using the form. This work resulted in the 100 collapsing into 73 one-page descriptions. These 73 are listed in Part II of Appendix A. Table 2 shows a sample method description written up in this form.

The 31

The next step in selecting the forecasting techniques to be used in the Handbook consisted of rating the 73 in terms of usefulness to the Corps. In this work the project team was augmented by consultants familiar with Corps planning activities over the years. The result of this intensive work was a list of 31 techniques. As before, we often found it possible to fold into a single description several allied techniques. In the list below, the prime technique is listed first, followed, where appropriate, by the allied techniques (from the list of 73) that were combined into the master description. For each of the 31 techniques a more detailed (5-10 page) description was prepared.

---

*Pamela G. Kruzic, David C. Miller, Arnold Mitchell, and Peter Schwartz.

Table 2

SAMPLE WRITE-UP

What Is It?

Name: CROSS IMPACT ANALYSIS

Definition/description: Comparison of individual forecasts, on a pairwise basis, to determine whether there are any interactions; or provides a systematic method for examining the interactions among several forecasts.

History/degree of provenness/promise: Devised by T. Gordon and O. Helmer in the late 1960s. Numerous applications--it works. High degree of promise.

What Do You Get?

Uses and Limitations: Comparison of forecasts and testing policies. Provides greater clarification of issues and better definitions of the risk and uncertainties in the subject being forecast, as well as a more complete and consistent picture of some future time period.
Limitations: Number of forecasts and possible method inflexibility.

Form(s) of output: A matrix of events in rows and columns depicting the interaction between events.

Level of detail: While extensive detail is possible (over 25 events), the procedure becomes tedious and evaluation complex.

Level of Confidence: Judgmental, but use of experts and probabilities provides for extensive feedback and review.

Span of forecast: Flexible (long- or short-term) and determined by nature of events.

How Do You Do It?

Procedures: Very systematic. Events are suggested with probabilities and year of occurrence. Events are then arranged in columns and rows. The interaction between events is shown in terms of mode (enhance, enables,...prevents); strength (10% ... 100%) and time lag (immediate ... x years).

What Do You Need?

Data requirements and availability: Forecasts--the source of these is often Delphi or panel but can be from any source.

People, including organizational back-up: Need "experts" to determine events, probability, and time of occurrence. Also, must evaluate the interaction among events.

Time: 1 day to 1 year, depending upon complexity: median 1 month.

Money: Range: modest to high. Depends upon complexity of events, type of "experts," and whether a computer is utilized.

Main Techniques	Allied Techniques Also Covered in Description
(1) Trend extrapolation	Exponential smoothing, regression analysis, moving averages, envelope curves, link-relative prediction, substitution forecasting, prediction of changeover points, Bayesian models
(2) Social trend analysis	Social indicators
(3) Precursor events	Breakthroughs
(4) Modes and mechanisms of change	Cycle analysis
(5) Box-Jenkins	--
(6) Probabilistic forecasting	--
(7) Subjective estimates of probability	--
(8) Environmental systems analysis	--
(9) Dynamic models	--
(10) Cross-impact analysis	--
(11) KSIM	--
(12) Input/output analysis	--
(13) Decision analysis	Decision matrices
(14) Relevance trees	Optimizing techniques
(15) Normex forecasting	--
(16) Policy capture	--
(17) Games	--
(18) Contextual mapping	--
(19) Risk analysis	--
(20) Mission flow diagrams	--

Main Techniques		Allied Techniques Also Covered in Description
(21)	Scenarios and related methods	--
(22)	Surprise-free projections	Canonical trend variation
(23)	Morphological analysis	--
(24)	Alternative futures	--
(25)	Divergence mapping	--
(26)	Authority forecasting	--
(27)	Surveys of attitudes	--
(28)	Panels	Brainstorming
(29)	Delphi	--
(30)	Life ways	Life style, psychographics
(31)	Synectics	--

The Ultimate 12

To select the ultimate list, the 31 techniques were rated for their appropriateness for inclusion in the Handbook. In addition to the SRI team and its consultants, votes were obtained from a group of Corps Planning Associates and several members of the Chief of Engineers office. All were asked which methods s/he would "surely include," "perhaps include," and which s/he would "discard." Information was also sought on which methods might be combined into one. A question concerning additional methods to consider produced no suggestions.

Voting on the 31 methods is shown below ("perhaps include" votes are not shown):

Forecasting Method	Surely Include	Discard
(1) Trend extrapolation	10	0
(2) Social trend analysis	5	0
(3) Precursor events	1	3
(4) Modes and mechanisms of change	4	3
(5) Box-Jenkins	2	1
(6) Probabilistic forecasting	5	2
(7) Subjective estimates of probability	2	5
(8) Environmental systems analysis	4	4
(9) Dynamic models	10	2
(10) Cross-impact analysis	5	2
(11) KSIM	9	0
(12) Input/output analysis	5	2
(13) Decision analysis	3	4
(14) Relevance trees	4	5
(15) Normex forecasting	4	2
(16) Policy capture	5	1
(17) Games	2	5
(18) Contextual mapping	0	8
(19) Risk analysis	5	1
(20) Mission flow diagrams	1	6
(21) Scenarios and related methods	7	1
(22) Surprise-free projections	3	2
(23) Morphological analysis	5	1
(24) Alternative futures	10	1
(25) Divergence mapping	2	1
(26) Authority forecasting	2	5
(27) Surveys of attitudes	3	2
(28) Panels	3	2
(29) Delphi	6	1
(30) Life ways	6	2
(31) Synectics	0	6

It will be noted that 18 methods received four or more "surely include" votes. It proved possible to include all except one of these (Environmental Systems Analysis) by combining several of the specific methods into a broader category. Twelve basic forecasting techniques were identified in this way, which incorporated some 25 of the 31 methods listed above. These 12 were arrayed under the three broad types of forecasting methods discussed in the introduction to this Handbook. These 12 are listed below, together with the methods each covers in the above list of 31. The result of these successive screening efforts is that about 50 of the initial list of 150 are covered in one way or another in the final 12 techniques selected for this Handbook.

Main Technique	Others Covered from the List of 31
Techniques Using Time Series and Projections	
(1) Trend extrapolation	--
(2) Pattern identification	Social trend analysis, precursor events, Box-Jenkins, Normex forecasting.
(3) Probabilistic forecasting	Subjective estimates of probability, risk analysis, relevance trees.
Techniques Based on Models and Simulations	
(4) Dynamic models	--
(5) Cross-impact analysis	--
(6) KSIM	--
(7) Input/output analysis	--
(8) Policy capture	--

Main Technique	Others Covered from the List of 31
Qualitative and Holistic Techniques	
(9) Scenarios and related methods	Surprise-free projections, authority forecasting, modes and mechanisms of change.
(10) Expert-opinion methods	Panels, surveys of attitudes, Delphi.
(11) Alternative futures	Morphological analysis, divergence mapping.
(12) Values forecasting	Life ways.

Nature of Descriptions of the Methods

In Sections III, IV, and V, the 12 forecasting techniques are described in a consistent format designed to show the planner what the technique will do, and hence, how appropriate it is for a given forecasting problem. Procedures for actually applying the technique are presented by case illustrations following the general description.

As indicated earlier, some of the techniques cover a variety of more specialized forecasting methods and some are confined to a single methodology. For example, "trend extrapolation" covers some 20 of the methods originally listed, whereas KSIM, policy capture, input-output, dynamic models, and cross-impact analysis have stood alone from the start.

The portions of the write-ups covering case examples required that we deal with a number of difficult issues. We use the word "difficult" because most users will already possess the knowledge and skills needed to make their own applications of certain methods. And most users will find some methods unintelligible, unusable, or completely inappropriate to his or her particular needs. The problem is, of course, that what falls in one category for some users will fall in the other category for other users. An explanation of procedures for a method that presumes little or no knowledge will result in a clear and helpful discussion for some users, while covering the obvious to users with a different background.

Frankly acknowledging the problem, we have sought a middle way in discussing forecasting procedures for the various methods. For each method explained, we have called out the basic steps. Thus, we have sought to provide an outline of what must be done in applying every method. We believe this approach makes the volume more useful.

In explaining procedures, we have made another basic decision. In many cases, it would be impractical or inadvisable for a Corps user to attempt to use a forecasting method unassisted by a specialist experienced in that method. Dynamic modeling or Box-Jenkins forecasts, for example, are not acquired and effectively used merely by reading a brief discussion about them. Hence each discussion includes comment on what level of expertise is required actually to forecast with the method.

In this connection, we have not attempted to transform the user into an expert practitioner of every method cited. Rather, we seek to afford an insightful appreciation of what is involved in applying a method. Hopefully, this approach to an explanation of procedures will provide several benefits to users. In the first place, it should assist in making tentative and then final selections of forecasting approaches best suited to specific situations.

Second, by learning what is actually involved in applying a given method, the user can anticipate possible difficulties to be encountered in applying the method. Third, an explanation of procedures should afford a basis for making approximate cost estimates--what it will cost to use a given method in the project. (Precise cost guidelines for forecasting activities are impossible to give because the scope, intensity, and other factors vary so widely from case to case.) Fourth, the explanation of procedures given here should help the Corps user determine what sorts of special skills are needed for a given method. Fifth, selection of technical consultants and an intelligent assessment of their work as it progresses should be facilitated.

All the examples used in Sections III, IV, and V concern or relate to forecasting problems involved in the planning of water resources in the Corps of Engineers. The sole function of each example is to illustrate and explain how a technique may be applied. To that end, some are based on past Corps applications, whether or not the technique was identified by name in the original research. Others are hypothetical but typical situations, which, for the sake of clarity, are simplified and exclude most details that would not contribute to understanding the application. A few techniques are extremely complex, and to use them requires both a major effort and highly specialized skills. For these, a general description of the process is furnished without illustration. It needs to be emphasized that none of these examples purports to show in detail how an actual piece of research was, or should be, carried out.

In view of the complexity of the forecasting methods covered in the Handbook, planners are encouraged to pursue the subject by studying the literature recommended as "further readings" in Section VI.

Forecasting and Planning

The distinction between forecasting and planning was a vital one in designing this Handbook. Forecasts are necessary for practically all good planning but in themselves forecasts are not plans. Intelligent planning requires problem identification, the formulation of alternatives, impact assessment, and evaluation. In all these steps, forecasts can serve as useful--sometimes essential--tools but they are only part of the processes of planning. This Handbook, therefore, should not be regarded as a planning manual.

In the winnowing process described earlier, the distinction between forecasting and the rest of the planning process was a principal guideline. Such techniques as systems analysis, decision analysis, mission flow diagrams, or contextual mapping were discarded because they do not produce forecasts, although they are very useful in planning. Similarly, techniques such as games or synectics may produce insights of great value in planning, but they are not primarily forecasting methods.

The distinction between planning and forecasting is by no means always clear cut. Because of this, the Handbook has purposely included several "aids to planning" that need not, in themselves, produce forecasts. Examples include survey techniques (discussed in Expert-Opinion Methods), analysis of social indicators (discussed in Pattern Identification), or cross-impact methods (discussed in Cross-Impact Analysis, KSIM, and Policy Capture). These "aids to planning" have been included because they directly provide grist for forecasting in much the same fashion that time-series data are essential to making trend extrapolations--that is, forecasts.

The Handbook is concerned with forecasting in several senses of the word. Some of the methods chiefly produce predictions (defined as prophecy); others are best adapted to identifying possibilities, whether or not they are predicted or predictable; still others are calculated to define forecasts in terms of physical plausibility or of desirability in values terms. All these are forecasts in the widest sense of the term, and all are useful in various circumstances and hence have been included.

FORECASTING ADJECTIVES

Forecasting can be:

- Short-term, mid-term, long-range
- Comprehensive, far-seeing
- Logical, deliberate, rational, definite
- Intricate, elaborate, complicated, complex, detailed
- Simple, clear-cut, solid
- Daring, subtle

Forecasting can also be:

- Makeshift, tentative
- Grandiose, unproductive
- Frantic, weird, unbelievable

Sophistication in Forecasting

In allocating planning funds it is usually assumed that the amount of effort should be roughly proportional to the size or cost of the project being investigated even though large and small projects generally contain the same basic elements. This is a good rule in the sense that one wisely takes greater care not to drop an ostrich egg than a hummingbird egg because one makes so much bigger a mess than the other. But in other senses the rule is far from wise.

There are two main criteria in choosing forecasting methods:

- What is the operational payoff of accuracy of forecasts?
- How much more accuracy will additional effort and/or sophistication buy?

Operational Payoff

Consideration of the operational payoff of accuracy involves both tangibles and intangibles. Where the real-life consequences or error are dire, sophisticated forecasts (i.e., forecasts presumed to be as accurate as possible) are justified. They also may be justified for such less tangible reasons as public or political pressure to put on a "good show," for their educational value to the planner, or even for the sheer pleasure of doing the best possible job.

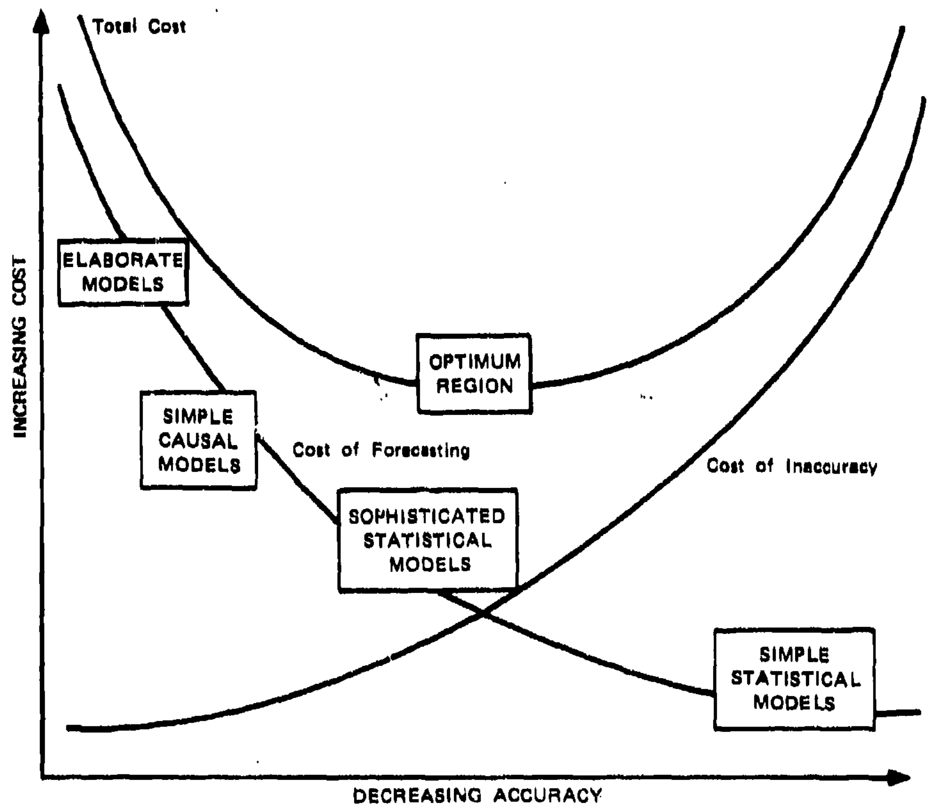
If it makes little operational difference whether the forecast is accurate or not, this may be a sign that the forecast is not needed at all or that the important aspect of the subject has been missed. Thus a "forecast" that an earthquake will occur is operationally much less useful than a forecast of when it will occur.

Operational payoff is perhaps best considered in terms of the "cost of forecasting" versus the "cost of inaccuracy." Although each circumstance is different, some basic principles apply. Figure 1 shows one way of determining the optimum degree of forecasting effort justified for a medium-range forecast, given the availability of reliable data. To enrich the diagram, several forecasting techniques that could be applied to a given problem are entered on the "cost of forecasting" line. In order for this approach to be useful the cost of forecasting must be an appreciable fraction of the cost of inaccuracy. If forecasting costs are, say, only 1 percent of the costs of inaccuracy, it is evident that almost any level of effort to reduce inaccuracy is justified.

Accuracy and Sophistication

In general, the more sophisticated the technique and the broader the base of factors considered the more accurate it is expected to be compared with simpler methods of forecasting the same development. If this is not true, the simpler method is always to be preferred.

Differences in accuracy among forecasting techniques can be very great. To illustrate, Table 3 shows errors in population forecasts using various methods. In this particular case the costs of the methods are so similar that one normally would select the one having the least error.



SOURCE: "How to Choose the Right Forecasting Technique" by John C. Chambers, Satinder K. Mullick, and Donald D. Smith, Harvard Business Review, July-August 1971, pp. 45-74.

FIGURE 1 COST OF FORECASTING VERSUS COST OF INACCURACY

Table 3

ERRORS IN POPULATION FORECASTS

Forecasting Method	Average Error in Percent: 10-Year Forecast	Average Error in Percent: 20-Year Forecast
Graphical extrapolation of past population growth	34.9%	61.8%
Projections based on exponential growth pattern	33.0	51.0
Projections based on linear growth pattern	14.2	18.8
Projections based on ratio of area to projected population of region	9.3	15.6
Projections based on S-shaped growth pattern	8.8	10.6

Source: Based on Frederick E. McJunkin, "Population Forecasting by Sanitary Engineers," Journal of the Sanitary Engineering Division, ASCE, Vol. 90, No. SA4, Proc. Paper 3993, August 1964, pp. 31-58.

In the case of time-series data directly representative of the items being forecast, it is usually possible, in a statistical sense, to prejudge what methods will yield the most precise results. This is no guarantee of accuracy, however because it assumes that the trends of the past will continue into the future. The "baby booms" and "baby busts" of the postwar years show that trends can change radically in even the most basic statistics.

One caution that cannot be repeated too often applies to many forecasting methods. Numerous techniques, such as risk analysis, optimization, and many models and simulations, deal with phenomena that can be defined only in terms of a series of discrete events having discrete outcomes. What cannot be defined in such terms must be ignored. Many complex phenomena for which we may wish to prepare forecasts simply do not lend themselves to such rigorous definition. If we insist on using such methods in such cases, the results are painfully predictable: no matter how sophisticated the effort in a technical sense, we will make unrealistic definitions of a topic, we will ignore or underestimate the significance of factors that cannot be handled, and we will end up with results that appear exact and precise but that may be disastrously deceptive.

There are other areas in which resort to sophisticated techniques can be a waste of time and effort. Some of these are listed below. In each case, the problem and the available forecasting tools must be considered individually.

- When the theory underlying the forecast is vague or, in fact, nonexistent. Example: hunch forecasts of trends in values or social movements.
- When reliability or pertinence of indicator data is questionable. Example: forecasts of technological breakthroughs in a new discipline.
- When the event is largely judgmental and narrowly dependent on a few people. Example: forecasts of political actions of foreign powers.
- When the forecast depends on so many events so complexly interrelated that many dozens of possible outcomes seem plausible. Example: detailed forecasts of the U.S. transportation system in the year 2000.

Despite such problems, many of the kinds of issues the Corps deals with are forecastable and responsive to advanced analytical treatment. Many of the major exceptions fall into the domain of forecasting people's wishes and attitudes, an area that partakes of many of the characteristics named above.

<u>The Techniques Compared</u>

In Tables 4 to 9, we have attempted to compare the methods discussed in this Handbook in a systematic fashion. The comparisons are useful as a starting point in selecting methods for various types of forecasting problems, but should be used with an awareness of their limitations. The tables necessarily reflect global conclusions that can be disputed in specific instances. For example, a given forecasting method can be applied to problems for which it is not particularly well adapted; conversely, the particular context of a forecasting problem may be such as to invalidate typical procedures. Further, a method may be good for cursory treatment but less than optimum for detailed analysis. If these kinds of limitations are borne in mind, the tabulations, which reflect "usual practice" provide a start in matching problem with appropriate technique.

Table 4

TASKS OF THE PLANNING PROCESS

Planning Task	Time Series and Projections			Models and Simulations					Qualitative and Holistic			
	Trend Extrapolation	Pattern Identification	Probabilistic Forecasting	Dynamic Models	Cross-Impact Analysis	KSIM	Input-Output Analysis	Policy Capture	Scenarios and Related Methods	Expert-Opinion Methods	Alternative Futures	Values Forecasting
Problem identification	X	X		X	X	X	X	X	X	X	X	X
Alternative formulation		X	X	X	X	X			X	X	X	
Impact assessment	X		X	X	X	X	X		X	X	X	X
Evaluation					X	X	X	X		X	X	X

Table 5

TYPE OF FORECAST

	Time Series and Projections			Models and Simulations					Qualitative and Holistic			
Nature of Results	Trend Extrapolation	Pattern Identification	Probabilistic Forecasting	Dynamic Models	Cross-Impact Analysis	KSIM	Input-Output Analysis	Policy Capture	Scenarios and Related Methods	Expert-Opinion Methods	Alternative Futures	Values Forecasting
Quantitative	X	X	X	X		X	X					
Qualitative		X		X	X	X		X	X	X	X	X
Normative		X			X	X		X	X	X	X	X

Table 6

AREAS OF ANALYSIS

Focus of Forecast	Time Series and Projections			Models and Simulations					Qualitative and Holistic			
	Trend Extrapolation	Pattern Identification	Probabilistic Forecasting	Dynamic Models	Cross-Impact Analysis	KSIM	Input-Output Analysis	Policy Capture	Scenarios and Related Methods	Expert-Opinion Methods	Alternative Futures	Values Forecasting
Economic	X	X	X	X			X		X	X	X	
Technological	X	X	X				X		X	X	X	
Social	X	X	X	X	X	X		X	X	X	X	X
Environmental	X	X	X	X	X	X		X	X	X	X	X
Values		X			X	X		X	X	X	X	X
Institutional					X	X		X	X	X	X	X

Table 7

QUALITIES OF FORECASTS

Quality of Forecast	Time Series and Projections: Trend Extrapolation	Time Series and Projections: Pattern Identification	Time Series and Projections: Probabilistic Forecasting	Models and Simulations: Dynamic Models	Models and Simulations: Cross-Impact Analysis	Models and Simulations: KSIM	Models and Simulations: Input-Output Analysis	Models and Simulations: Policy Capture	Qualitative and Holistic: Scenarios and Related Methods	Qualitative and Holistic: Expert-Opinion Methods	Qualitative and Holistic: Alternative Futures	Qualitative and Holistic: Values Forecasting
Level of detail (fine, medium, gross)	all	all	all	medium-gross	medium-gross	gross	fine	gross	medium-gross	all	gross	medium-gross
Span of forecast (short, medium, long)	short-medium	medium-long	medium-long	medium-long	medium-long	long	short-medium	medium-long	medium-long	all	medium-long	medium-long
Time to make forecast (days, weeks, months, >year)	days	weeks	weeks	months	weeks	weeks	months-years	days	weeks-months	days-weeks	weeks-months	weeks months
Cost of making forecast (low, medium, costly)	low	medium-costly	medium	costly	low-medium	low-medium	costly	low-medium	medium	low-medium	medium-costly	medium-costly
Number of variables forecast (one, several, many)	one	several-many	several	several	several	several	many	several	many	all	many	many
General understandability of forecast (low, medium, high)	high	medium	medium	medium-high	medium high	medium-high	low	high	high	high	medium-high	medium
Versatility of method (narrow, medium, broad)	all	medium	medium	medium-broad	medium-broad	medium-broad	narrow-medium	broad	broad	broad	broad	narrow
Ease of applying method (easy, medium, difficult)	easy	difficult	difficult	medium-difficult	medium-difficult	medium-difficult	medium difficult	easy	easy-medium	easy-medium	medium-difficult	difficult
Assistance needed to make forecast (none, routine, sophisticated)	none-routine	routine-sophisticated	routine-sophisticated	sophisticated	none-sophisticated	routine-sophisticated	sophisticated	sophisticated	none-sophisticated	none-sophisticated	none-sophisticated	none-routine
Type of comparisons (single events, many events, interactions)	single	single	single-many	interactions	interactions	interactions	interactions	interactions	many-interactions	single-many	many-interactions	many

Table 8

RESOURCES NEEDED TO USE THE TECHNIQUES

Type of Resource	Time Series and Projections: Trend Extrapolation	Time Series and Projections: Pattern Identification	Time Series and Projections: Probabilistic Forecasting	Models and Simulations: Dynamic Models	Models and Simulations: Cross-Impact Analysis	Models and Simulations: KSIM	Models and Simulations: Input-Output Analysis	Models and Simulations: Policy Capture	Qualitative and Holistic: Scenarios and Related Methods	Qualitative and Holistic: Expert-Opinion Methods	Qualitative and Holistic: Alternative Futures	Qualitative and Holistic: Values Forecasting
Data												
Historical	X	X	X	X	X	X	X					X
Public opinion								X				X
Expert opinion				X	X	X		X		X	X	X
Imagination/speculation					X	X		X	X	X	X	X
Personnel												
Generalists				X	X	X		X	X		X	X
Methodologists				X	X	X	X			X		X
Subject experts		X		X	X	X	X	X	X	X	X	X
Mathematicians/statisticians	X	X	X	X		X	X					
Writers/communicators									X		X	
Literature searchers									X		X	X
Computer programmers		X	X	X	X	X	X					
Questionnaire & survey experts										X		X
Physical												
Computers	X	X	X	X	X	X	X					
Programmable hand calculators	X							X				
Existing computer programs	X		X	X	X	X	X					
Statistical packages	X	X	X				X	X				
Data banks	X		X				X					

Table 5

SPECIAL USES OF THE TECHNIQUES

Special Use	Time Series and Projections: Trend Extrapolation	Time Series and Projections: Pattern Identification	Time Series and Projections: Probabilistic Forecasting	Models and Simulations: Dynamic Models	Models and Simulations: Cross-Impact Analysis	Models and Simulations: KSIM	Models and Simulations: Input-Output Analysis	Models and Simulations: Policy Capture	Qualitative and Holistic: Scenarios and Related Methods	Qualitative and Holistic: Expert-Opinion Methods	Qualitative and Holistic: Alternative Futures	Qualitative and Holistic: Values Forecasting
"Getting into the future"		X		X	X	X			X		X	X
Stimulates insight into societal issues		X	X	X	X	X		X	X	X	X	X
Stimulates insight into modes of societal change	X	X		X	X	X	X	X	X	X	X	X
Surfaces personal assumptions about today and the future			X		X	X		X	X		X	X
Offers citizen participation in planning and decision making						X		X	X	X	X	X
Well adapted to communicating results to the public	X	X		X				X	X	X	X	

Section III

FORECASTING TECHNIQUES USING TIME SERIES AND PROJECTIONS

Introduction

Three classes of forecasting techniques are discussed in this section of the Handbook: trend extrapolation, pattern identification, and probabilistic forecasting. These methods are all based on series of historical data that are analyzed in various statistical ways to arrive at forecasts of the future.

In general, these techniques are the most commonly used, the most easily used, and the most understandable of all forecasting methods. Even so, some require advanced mathematical skills and utilize subtle concepts. The methods are remarkably flexible in the kind of problem they can treat and the level of detail of results. The methods are often used by themselves to generate forecasts on specific subjects; they also are extensively used to generate inputs to many forecasts based on models, and to help quantify trends utilized in more qualitative, holistic types of forecasting.

TREND EXTRAPOLATION

General Description

Abstract

Trend extrapolation is the general name for a variety of mathematical forecasting methods all of which determine future values for a single variable through some process of identifying a relationship valid for the past values of the variables and a solution for future values. Although the technique is generally useful for only a single variable, this variable may be highly complex in that it may reflect numerous trends. It should be recognized that since only quantifiable variables may be forecast through extrapolation, a bias is introduced against that which is nonquantifiable. A major limitation of extrapolatory methods is that they are not able to deal with unanticipated changes in the historical pattern of the data. Trend extrapolation includes such methods as "eye-balling," moving averages, exponential smoothing, substitution and growth curves, envelope curves, and simple and multiple regression.

Definition

Trend extrapolation is a family of quantitative forecasting techniques all of which depend on extending, or extrapolating, time-series data in accord with specified, usually mathematical, rules. The extrapolations constitute the forecast.

The specific methods used to extrapolate include a variety of growth curves (such as Pearl and Gompertz curves), straightline extrapolation curves, cycles of various sorts, regressions, moving averages, link-relative predictions, exponential smoothing, and many others. Easily the most-used method of extending time-series data is "eye-balling."

The data used are usually actual counts of the phenomenon under investigation, such as population, flow rates, events per units of time, or dollars earned. The methods also can be used with proxy data or other kinds of indicators, provided they are available for a long enough period to reveal a pattern of development that can be used as a basis for extrapolation.

Trend extrapolation depends on the hypothesis that past and present trends will, in the future, develop in the same direction and at the same rate as in the past, unless there is a clear indication of a shift in trends. Such shifts--not always foreseen--account for some recent spectacular errors in extrapolatory forecasts. Population, inflation, and oil prices are recent examples, along with that perennial favorite, the Dow Jones average.

Assumptions

In using methods based on trend extrapolation it is assumed that:

- The important variables in a persistent phenomenon can be identified.

- Sets of data can be assembled that describe the interrelationships among the important variables--at any one point in time, and also over a series of successive intervals of time.

- Data representing each point in time are--or can be converted to be--directly comparable with data representing other points in time for the same variables.

- Underlying causal factors are responsible for variations in data values, so that persistent patterns in the directions or rates of data variations provide the basis for significant cause-effect explanations.

- The direction and rate of data variations in preceding time intervals is likely to persist in successive time intervals.

More recently, and by no means universally, trend extrapolations sometimes recognize that the structure and dynamics of a phenomenon--e.g., population density in a given locality--often impose predictable limits on directions and rates of trend developments. When these limits are known, their implications are useful in predicting future directions and rates of trend development.

History

The instinctive use of trend extrapolation goes back to the dawn of man. Surely, even the most primitive man was confident that day would follow night simply because "time-series analysis" showed no exceptions. In a more sophisticated fashion the ancient Greeks developed theories of cosmology by noting changes in positions of stars over many years.

Trend analysis and projection has in recent decades enjoyed an expansion that amounts to a boom. Among the causal factors explaining this rising interest are:

- The growing complexity and interdependence of civilization. Trends in one sector are apt to cause important effects immediately or in the future in many other sectors. The human environment is increasingly human-made, abstract, and subject to rapid shifts resulting from human decisions and actions. Trend analysis and forecasting has become an indispensable tool for understanding what is happening to us.

- As society grows more complex, more and more transactions are formalized and recorded. One result of this is more and more--and in some cases more and more accurate--time-series data. Thus, opportunities for trend projections based on existing data are more and more widely and readily available.

- The "computer revolution" has encouraged the development and use of diverse, sophisticated, and often powerful methods that enable us to analyze and project trends rapidly and at relatively low costs.

For such fundamental reasons as these, much--perhaps even most--contemporary research in economics, political science, and the other behavioral and social sciences is centrally dependent upon or makes heavy use of trend analysis and projection methods.

Main Uses

Trend extrapolation is not only one of the oldest but also one of the most widely used futures forecasting methods. So widespread and common are such methods that it is quite impossible to identify "main uses." It is, however, widely used in the physical biological, behavioral, and social sciences; in the management of organizations and institutions; in every realm of technology; and in marketing and finance. The Corps has used it in scores of areas, such as population estimates, water demand, recreation projections, flood damage probabilities, and so on. Indeed, one is hard-pressed to identify a field of human enterprise in which trend extrapolation is not a significant tool.

Limits and Cautions

The limits of trend extrapolation methods are simply stated but observed only with major effort and difficulty. They are the limits of the data base, of reliability, and of validity.

Data base limitations refer to the fact that information on many key variables has been recorded for periods too brief to permit clear analysis of trends. Worse, data for different periods may not in fact be parallel although they may be presented as such. Definitions and standards of data acquisition and recording vary greatly from time to time, place to place, and situation to situation: accordingly, the challenge of comparability of data is often severe.

The reliability of trend extrapolation also involves the issue of technical competency. A forced-fitting of data points to a preconceived curve may conceal more than it reveals. Insufficient tests of statistical significance may suggest important correlations where none actually exists or obscure the fundamental relationships sought.

The validity problem goes beyond those of data reliability and technical competence. Even when data are accurate and standardized, and when the extrapolation method has been used with great competence, fundamental issues remain unresolved. Consider, for instance, measures of environmental quality. There is not as yet--in fact, may never be--general agreement as to which variables best measure environmental quality. Such being the case, different observers will accept or reject different subsets among the candidate variables. Which particular subset of variables is the most accurate and adequate measure of environmental quality? No one can say--or rather, any one can say, but no one can offer satisfactory proof that his or her view is most nearly correct.

Other Techniques

As mentioned above, trend extrapolations are used by nearly everyone for nearly everything. Virtually every other method discussed in this Handbook--and many not mentioned as well--can be used as well as or better than the trend extrapolation method in some application. Few if any methods, on the other hand, can be or are used in as many different applications as are trend extrapolation methods.

Product or Result

Simple or elaborate, the end-result of a trend extrapolation study consists of a set of data points with associated measures of their interrelationships. These relationships can be shown among data points for a single time period, and/or among data points for two or more time periods. In physical form, the product may be a series of tabulations, a series of graphic displays showing trend curves, or something as elaborate as an interactive computer model in which implicit relationships may be called up and explored at will.

Level of Detail

Typically, results are fine grained, reflecting the nature of most time-series data. Grosser results will come from extrapolation of grosser data, such as poll data on overall satisfaction with housing.

Level of Confidence

Confidence in the result of a trend extrapolation study is largely gauged by two factors: the extent and quality of the data base used, and the perceived validity of the underlying explanatory model. Consider, for example, two hypothetical studies, one dealing with U.S. population growth trends since 1790 and the other treating political radicalism in the United States during the past decade. Presuming identical standards of professional competence and dispassionate interest in the two topics, the population study must intrinsically inspire greater confidence. The population study enjoys an unbroken set of time-series data for a period of nearly two centuries, while the radicalism study, by definition, is limited to 10 years. The topic of the population study is clear--how many citizens were alive and counted at given times--while the topic of the radicalism study is obscure and controversial.

The population study uses simple, directly applicable data while the radicalism study must necessarily rely on such proxy data as can be scraped together. For such fundamental reasons, the extent and quality of data used in a trend extrapolation, together with the demonstrable validity of a study's assumptions, greatly influence the level of confidence such studies enjoy.

Communicability of Results

Because trend extrapolation methods are universally used, the essence of the method and the direct import of the findings are readily conveyed, even to persons with no special training in such methods. The proofs and assumptions on which the findings are based are another matter. Here at once arise all the issues mentioned above under "Limits and Cautions." Appreciation of statistical and other (often complex) analytic methods may also be difficult or impossible to convey.

Credibility of Results

The credibility of a trend extrapolation study depends almost wholly on the specific situation. For example, many people will accept the general shape, direction, or slope of a trend curve without understanding or questioning underlying assumptions. In that sense, a trend extrapolation study may well enjoy more credibility than it deserves. People also may be either totally uncritical or, in other cases, relentlessly critical of the data base for a given study. Finally, there is nearly always at least some controversy about the significance of a given trend with respect to a given topic. For example, people who agree that the U.S. birth rate is now dropping often disagree sharply about the implications of current trends for the future demographic structure of the United States.

Span of Forecasts

Because trend extrapolations are so widely and diversely used, their time spans vary enormously from application to application. The U.S. Census Bureau, for example, regularly projects population trends for 50-year periods. By contrast, few econometricians care to project economic trends further than five years in advance.

The nature of the topic under study also helps determine appropriate time spans. Long-term demographic trends, for example, may develop over many years before they are detected. Trends in, say, securities markets, by contrast may develop dramatically over a few days or weeks because securities trading is a fast-moving, volatile enterprise.

Resources Needed

All extrapolatory methods require the availability of reliable historical data. Beyond that, resources range from a French curve, a slide rule, and a few minutes for the simpler methods, to advanced statistical skills, a computer, and elaborate programs for complex methods. Generalities do not apply concerning time and cost requirements. "Eye-balling" of some trends can be done in seconds at essentially no cost. At the other extreme, mathematical analysis of complex data series and computer programming to derive extrapolations can require weeks or months of time and many thousands of dollars. Very rarely do trend extrapolations of single variables cost over $10,000.

Procedures

In general, trend extrapolation is easy to do. Once appropriate time-series data are plotted, the rhythm of the curve is often self-evident. In some cases, all that is required to extrapolate is a ruler or a French curve. For more complex situations, planners unfamiliar with statistical mathematics will need help. Very often this help is readily available in the form of computer programs for curve fitting.

Case Example

Trend Extrapolation Via Curve Fitting

The mathematical assumption underlying trend extrapolation is that a relatively orderly progression of historical data will continue into the future. The basic procedure for forecasting (once the historical data have been selected) involves determining the appropriate form of the curve, and extrapolating the future values using the appropriate curve equation.

Curve Fitting

If a computer curve-fitting program is available, one can use the computer to determine the appropriate form of the curve.

For example, the CURVE* analysis performs a least squares fit for six types of curves. The six curve types are shown below, where y is the dependent variable.

$$y = A + B\,x \qquad y = A + (B/x)$$

$$y = A(x^{B}) \qquad y = 1/[A + (Bx)]$$

$$y = A(e^{Bx}) \qquad y = x/[A + (Bx)] \quad .$$

To perform curve fitting, the user types in the values for the independent and dependent variables. The computer then prints a table containing the general curve equation, the calculated values of A and B, and the index of determination for each curve. The closer the value of the index of determination is to 1, the better the fit to the respective curve equation. In Table 10 it is evident that curve type 2 gives the best fit. The calculations are performed by appropriate transformations of the variables. A simple linear regression is then used to calculate A and B. A sample computer output is shown in Table 10.

If a computer program is not available, the fit must be done by hand. First the data must be plotted on graph paper to see the form of the curve. If the plot shows a nonlinear form, historical data must be transformed to fit the basic linear least squares form.† Then a least squares fit must be performed to

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*CURVE is available from Tymshare Incorporated as part of their statistical package (STATPAK).

†The least squares fit uses the following basic linear equation: $y = A + Bx$.

Table 10

SAMPLE COMPUTER CURVE FIT OUTPUT

Least Squares Curves Fit

Curve Type	Index of Determination	A	B
1. Y=A+(B*X)	0.59624586E-01	5.9440559	-0.25174825
2. Y=A*EXP(B*X)	0.93679343E-01	6.0601784	-0.70761195E-01
3. Y=A(X↑B)	0.52892795E-02	4.9421407	-0.51773591E-01
4. Y=A+(B/X)	0.37433361E-01	5.518248	-1.4262832
5. Y=1/(A+B*X)	0.13587205	0.15059108	0.22302697E-01
6. Y=X/(A+B*X)	0.41107133E-02	0.27737894E-01	0.33414747

Details for 2:

2. Y=A*EXP(B*X) is an exponential function. The results of a least-squares fit of its linear transform are as follows:

X-Actual	Y-Actual	Y-Calc	Percent Difference	
1.0	3	5.6461734	-46.8%	
1.5	4	5.449901	-26.6	
2.0	5	5.2604514	-4.9	
2.5	6	5.0775875		18.1%
3.0	7	4.9010803		42.8
3.5	8	4.7307089		69.1
4.0	7	4.5662599		53.2
4.5	6	4.4075274		36.1
5.0	5	4.2543129		17.5
5.5	4	4.1064244	-2.5	
6.0	3	3.9636768	-24.3	
6.5	2	3.8258913	-47.7	

determine the values of the parameters A and B.* Finally, future values of y can be extrapolated or calculated using the equation just determined.

Trend Extrapolation

Although several different forms of growth curves are available for forecasting, the S-curves are most commonly used.† Figure 2 illustrates two such growth curves, the Pearl curve, and the Gompertz curve. The Pearl curve is used in this example to illustrate the trend extrapolation forecast.

Consider, as an example of this approach, the problem of a community that has decided to limit its population growth to some fixed level--say 700,000. We wish to forecast the community population growth from 1970 to the year 2000 if the total is to remain below the limit. First, the historical data for the population of the community are plotted on semilog paper as shown in Figure 3. Determining from the plot that the curve form is the Pearl curve, the historical data are transformed to allow for curve fitting by the least squares method. The historical data and transformed values are shown in Table 11.

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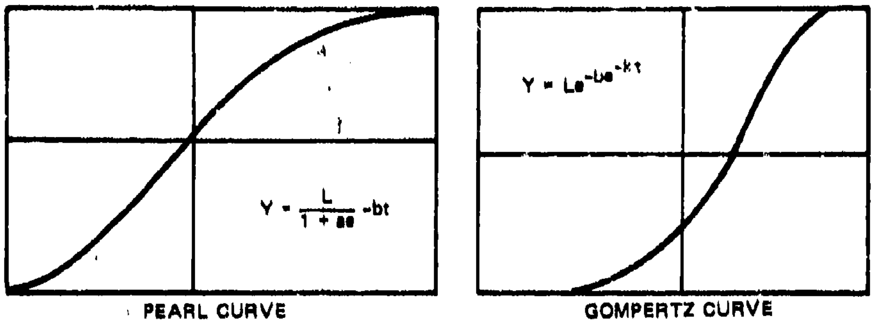
*Use the following equations to calculate A and B for the least square fit (n equals the number of xy pairs).

$$A = [(\Sigma y\ \Sigma x^2) - (\Sigma x\ \Sigma xy)]/[n\Sigma x^2 - (\Sigma x)^2]$$

$$B = [n\Sigma xy - (\Sigma x\ \Sigma y)]/[n\Sigma x^2 - (\Sigma x)^2]$$

†"It is generally believed that technical time-series data in arithmetic scales produce S-curves, reflecting a slow start, exponential growth, then a leveling off against some limit produced by nature or man" (Bright, 1972).



The equation for the Pearl Curve is:

$$Y = \frac{L}{1 + ae^{-bt}} \tag{1}$$

where:

Y = population, unknown for the present to the year 2000

L = upper limit to growth, 700,000

a = parameter, determine from historical data

b = parameter, determine from historical data

t = time.

For ease of manipulation, we first rearrange Equation (1) and take the logs as shown below:

$$\frac{L}{Y} - 1 = ae^{-bt} \tag{2}$$

$$\ln\left(\frac{L}{Y} - 1\right) = \ln a - bt \tag{3}$$

If we now let $Y' = \ln\left(\frac{L}{Y} - 1\right)$ we can use the following expression for the least squares fit:

$$Y' = \ln a - bt \tag{4}$$

FIGURE 2 S-CURVES WITH A DESCRIPTION OF THE PEARL CURVE

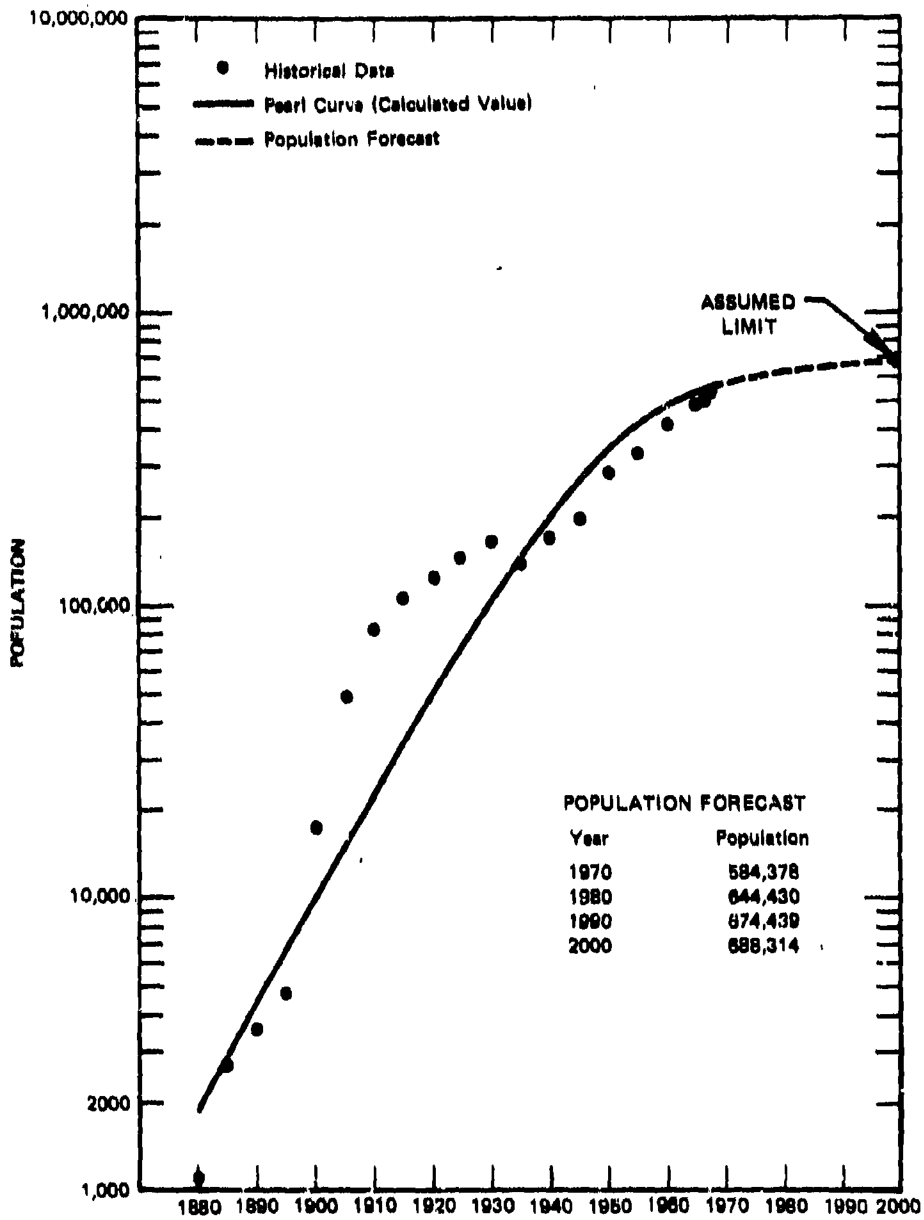


FIGURE 3 COMMUNITY POPULATION

Table 11

COMMUNITY POPULATION--
ACTUAL AND TRANSFORMED DATA

Year	Actual	Transformed*
1876	1,000	8.85
1880	1,100	6.45
1885	2,700	5.55
1890	3,600	5.26
1895	4,800	4.97
1900	17,600	3.66
1905	48,800	2.59
1910	82,000	2.02
1915	103,900	1.75
1920	123,400	1.54
1925	144,600	1.34
1930	162,600	1.19
1935	136,400	1.19
1940	165,100	1.17
1945	198,100	0.93
1950	280,800	0.40
1955	337,200	0.07
1960	407,800	-0.34
1965	478,200	-0.77
1966	498,700	-0.91
1967	518,300	-1.05

*Assuming an upper population limit (L) of 700,000 people we use the following expression to transform the data,

$$Y' = \ln\left(\frac{L}{Y} - 1\right) .$$

Thus, in 1967 the transformed value is calculated as follows:

$$Y' = \ln\left(\frac{700,000}{518,300} - 1\right) = -1.05$$

The transformed data are used to calculate the A and B parameters for the Pearl curve based on the least squares method presented previously. Now the historical trend can be extrapolated by using Equation 4 in Figure 2 to forecast the population between 1970 and 2000. Since we have used and forecasted the transformed values, it is necessary to invert or change the transformed values to actual population numbers. Table 12 shows the calculated as well as the inverted values in numbers of people. The forecasted population values for 1970 to the year 2000 are also shown in Figure 3.

The Pearl curve shows that an annual growth rate between 1970 and 2000 of less than 1 percent is permissible if the population is to be held to 700,000 people in the year 2000.

Trend Extrapolation for Small Areas Using Proxy Data

Many water resources projects must be planned and implemented in small geographic areas, or in thinly populated rural regions. In such situations, forecasting prospects of future growth in the area can be extremely difficult. Existing data bases are likely not to be sufficiently disaggregable, or to use awkward boundaries. Since appropriate time-series data are not available, it is not feasible to use direct trend extrapolation techniques.

The problem is regularly encountered in market research, and in survey research throughout the behavioral and social sciences, as well as in water resources planning. The Bureau of the Census is keenly aware of the problem, and makes everv effort to assist. For example, the Bureau's Small Area Data Notes is widely consulted

Table 12

CALCULATED VALUES FOR COMMUNITY POPULATION
1876-2000

Year	Calculated Values* Transformed	Calculated Values* Population
1876	6.2432	1,356
1880	5.9083	1,894
1885	5.4897	2,875
1890	5.0712	4,360
1895	4.6526	6,606
1900	4.2340	9,991
1905	3.8154	15,072
1910	3.3968	22,654
1915	2.9783	33,857
1920	2.5597	50,194
1925	2.1411	73,542
1930	1.7225	105,978
1935	1.3040	149,295
1940	0.8854	204,237
1945	0.4668	269,492
1950	0.0482	341,225
1955	-0.3704	413,674
1960	-0.7889	480,835
1965	-1.2075	538,360
1966	-1.2912	548,496
1967	-1.3749	558,160
1970	-1.6263	584,378
1980	-2.4634	644,430
1990	-3.3006	674,439
2000	-4.1377	688,314

*Based on the following equation:

$$Y' = \ell n\ a - bt$$

The parameters A and B were determined by the least squares method using the historical transformed data from Table 11.

(monthly, 8 to 12 pages, $5.50 per year, including 4 to 6 issues of Data Access Descriptions).

A simple and potentially useful method that addresses this problem from the Corps' perspective has been proposed by Burnham H. Dodge, consultant to this study and former planner in the Institute for Water Resources. Dodge's method is qualitative, exploits local sources of information, and would appear to be eminently practical where no more direct data are available. The method can be applied for areas as small as a part of a single county. While the method has not been actually used to date, it appears to deserve a fair trial.

To use the method, the forecaster first makes a base-line forecast. The base-line forecast is prepared by scaling down to the area of interest existing data from the next largest aggregation that includes the area of interest.

It is acknowledged that the base-line forecast is apt to give a distorted picture of future growth in the small area. Localized factors not reflected in trends for the larger region will probably have a substantial impact on actual future growth in the small area. The method seeks to modify the base-line forecast by systematically identifying and accounting for the most important localized influences on future growth. Dodge proposes a list of nine such local factors:

- Population density in the small area, compared with nearby areas.
- The ratio of families whose heads are of child-bearing age to the total number of households in the area.

- The extent and quality of community facilities.
- The amount of land available for future development.
- Evidence of current community preference for residential development or for industrial development.
- Extent of harmony among various community interests.
- Personal income levels in the area, compared with those in nearby areas.
- Tax and bond capacity to build additional community facilities.
- The reputed quality of the local school system.

This list is meant to be suggestive rather than exhaustive. Clearly, in any particular area not all factors will be of equal weight in determining the area's future growth. Indeed, Dodge argues that a forecaster familiar with the area can sift systematically through such a list and decide how important each factor is. To do so requires compiling pertinent information from formal and informal local sources, such as:

- Local and regional governments
- Local newspaper files
- Chambers of commerce
- Business and social organizations
- School boards
- Long-time residents of the area.

Having compiled his list of crucial local factors and as much pertinent information as possible, the forecaster can address three basic questions for each factor considered:

(1) Has the importance of this factor changed, compared with the past? If so, will that change have a positive or a negative influence on the rate of future growth in the area?

(2) Given the factor's current significance, does it now tend to encourage or discourage development in the area?

(3) Taking Points 1 and 2 together, will this factor in the future be a positive or a negative growth factor in the area?

The method is shown in the form of an evaluation table in Table 13.

In addition to the points already discussed, the table provides a column in which the forecaster can record the rationale used in making estimates. As indicated, a seven-value scale (-3 to +3) has been used in making judgmental weightings of each factor. Since the factors given in this particular table number nine, the range of weighted values is from -27 (9 × -3) to +27 (9 × +3). A -27 score reflects the forecaster's estimate that the area is in for a severe decline in growth, a 0 score means that historic growth trends are expected to continue, and a +27 score indicates that population in the area is expected to boom.

The factors shown in Table 13 all represent traditional forces that contribute to positive or negative growth in any small area. In addition, the forecaster must be alert to special novel factors in the area--"discontinuities," in futurist jargon--that could affect future growth rates. Among these, the potential impact of the proposed water resources project itself should be given particular attention.

Table 13

FACTORS IN POPULATION GROWTH

Factor	Effect on Population Change: Past	Present	Historical Situation	Present Situation	Future: + or -	Future: Weighted	Rationale for Future Effect of Factor
Population density--relation to other areas					-	-1	Low past density has been positive. Present density is neutral. Assuming trend will not stop suddenly, it will become increasingly negative.
Above							
Same		x		0			
Below	x		+				
Ratio of child bearing families to total population					-	-3	Source of locally generated population in a declining trend.
Greater	x						
Same							
Less		x	-	-			
Infrastructure					+	+1	Record of adequacy supports expectation of ability to meet needs of larger population.
Adequate	x	x	+	+			
Inadequate							
Space available					+	+3	
Ample	x	x	+	+			
Limited							
None							
Community policy					-	-2	Employment attracts more people than residential opportunity.
Favor industry	x		+				
Favor residential		x		-			
Community cohesion					-	-3	Peace and harmony are more attractive than conflict and controversy.
Common interests	x		+				
Conflicting interests		x		-			
Personal income re other areas					+	+3	High personal income level is a positive influence in this particular area.
Above		x		+			
Same							
Below	x		-				
Revenue potential					+	+3	Ability to finance community facilities required by population increase is positive.
Adequate		x		+			
Inadequate	x		-				
School system					+	+2	Trend points to continued improvement.
High quality							
Average quality		x		0			
Low quality	x		-				
Net effect					+1	+3	

The Dodge method has been presented here in terms of the individual project planner. The simplicity of the method is such that it lends itself well to use with coordinating agencies and for early, significant citizen involvement in project planning.

In conclusion, the foregoing method for estimating future growth potential in a small area is a simple, qualitative, best-judgment estimation method. While the method has never been tested in actual use, it seems straightforward and adaptable, and should be well worth trying in those many situations where more direct, rigorous approaches are not feasible.

PATTERN IDENTIFICATION

General Description

Abstract

Forecasting methods based on pattern identification seek to recognize a developmental pattern in historical data and to use this often obscure pattern as the basis of forecasting future events. The method is useful both for time-series data, where more direct extrapolating methods do not work, and for interpreting numerous social trends. The Box-Jenkins method is an example of the former and Normex forecasting and analysis of precursor events are examples of the latter. Pattern identification methods sometimes suffer from a poor data base, varied interpretations, and hence questionable reliability of findings.

Definition

It was Thomas Campbell (1777-1844) who first observed that "coming events cast their shadows before." Ever eager to avoid the worst and exploit the best, humanity has tried to discern the outlines of what will be amid the shadows of what is. The results are rarely satisfying. Mingled and overlapping in the darkness, shadows and silhouettes tell us as much about what never was as about what must yet be.

Shifting from the metaphorical to the practical, what information is there in shadows, silhouettes, and bare profiles? How is it that we can recognize a friend viewed through a translucent screen? The answer is that in silhouettes and shadows we can recognize patterns. Further, if a pattern can be recognized, what comes next often can be identified. This ability is the basis of forecasting via pattern identification.

Pattern recognition and prediction are useful only where less direct methods, such as trend extrapolation, are inadequate. In the case of time-series data with a readily apparent trend, extrapolating methods are generally cheaper and more easily understood than more sophisticated methods such as Box-Jenkins. The Box-Jenkins method is a relatively recent quantitative forecasting approach designed to handle complex time-series data where no ready pattern to the data is apparent. Unlike most other quantitative techniques, Box-Jenkins does not require a clear definition of the trend. In fact, the method is intended to discover the pattern of the trend. This is accomplished by multiple iterations of the data, with each iteration providing information that allows the next to more closely approximate the actual pattern of the data. In complexity, Box-Jenkins lies between multiple regression analysis and computer simulation models. The method forecasts only a single variable.

Normex forecasting is so called because it combines normative objectives (i.e., need-oriented) with exploratory forecasting (i.e., extrapolation of trends) to arrive at forecasts felt to be superior to either normative or exploratory approaches alone. In effect, the approach seeks to combine change patterns in several areas to define the joint outcome. A major advantage of the technique is that it provides the planner with a frequency distribution about some forecasted event. While the method is relatively inexpensive, it does require the collection of large amounts of historical data.

Pattern identification is also fundamental to interpreting precursor events, leading and lagging indicators, and many kinds of social trends. In contemporary futures research, the analysis of precursor events has been most closely identified with technological, and especially "break-through" forecasting. Similarly, pattern analyses of social phenomena usually deal with redirections of trends, ranging from shifts in political sentiment to basic phase-changes of cultural norms. Social indicators frequently substitute for direct measures in this sort of work.

Assumptions

The most fundamental assumption in these forecasting techniques is that events do have patterns. Second, it is assumed that discernible patterns are harbingers of things to come--an assumption that presumes the past is indicator of the future. Third, in approaches utilizing indicators rather than direct measures, assumptions must be made concerning the validity and completeness of the indicator.

History

Use of trends to predict future social patterns goes back to early times. Recent years have seen an enormous expansion in social trend and social indicator research, spearheaded by the federal government and by such private organizations as the Russell Sage Foundation and the Social Science Research Council.

The Box-Jenkins method emerged from a different line of developments. It was developed in the late 1960s by Professors G. E. Box and G. M. Jenkins, and was first published in 1970 in their book, Time Series Analysis.

The Normex approach was well described by Brown and Burkhardt in 1968 in a paper that illustrated the combined use of trend extrapolation and normative forecasts. Mathematical procedures applicable to the Normex technique were published by Blackman (1973). Normex has been applied to planning for jet engines and the computer memory market. The technique is still undergoing development.

Main Uses

Pattern recognition methods are most useful where data are fuzzy, indirect, or so complex as to be obscure as to what is included. Social analysis based on patterns is used chiefly in the fields of

- Public policy setting
- Program development and assessment
- Long-range corporate planning
- Market research.

Precursor studies focus primarily on technological forecasting. Box-Jenkins is applicable to any kind of problem as long as the desired forecast has an extended time span, the data composing the time series are complex, and a relatively high degree of precision is both required and meaningful. It is also important that the Box-Jenkins method provides information on the statistical error in the forecast, independent of other tests.

To date, Normex forecasting has been used largely to estimate future markets for high-technology products and services. However, the methodology is general and should be applicable, for example, to forecasting demand for recreational facilities at a reservoir. Through its ability to forecast both the mean and variance associated with future technological performance parameters, the Normex technique provides the capability of evaluating the level of uncertainty associated with a forecast. Hence, a measure of the extent of possible error is presented along with the forecast.

Limits and Cautions

There are several limits and cautions:

- Most basic is the problem of assessing the true validity of a pattern for predicting. In social affairs, no comprehensive theory of societal change exists. Hence, all forecasts based on trends and indicators of trends must be regarded with caution.

- The fallacy of the so-called intervening variable is a trap in forecasting from precursor events. This fallacy imputes causative powers to what actually is merely coincidence. (Example: is inflation the cause of economic recession or the reverse, or were still other factors responsible for both?)

- Forecasts based on time-series data are only as good as the data. Data quality is often more difficult to judge in complex series than for the simpler series typically used in trend extrapolations.

- The forecaster must always be aware of the limitations of forecasts based on extensions of past patterns to future events.

Other Techniques

Many forecasting methods utilize pattern identification in one or more of their aspects--indeed, pattern recognition is basic to the holistic forecasting techniques discussed later. The methods mentioned here differ from the others chiefly in the explicitness with which patterns are sought out and extended into forecasts.

Product or Result

Ideally, pattern identification methods result in arrays of time-series forecasts presented in tabular or graphical form. Box-Jenkins specifically provides the most likely value and an upper and lower bound to the probability range. Normex forecasts are usually defined in terms of mathematical uncertainty. Supporting histograms and graphs often show (for example) sales as a function of a performance parameter. Implicit in such forecasts are models or patterns. In some cases these patterns are usefully developed into complex computerized programs. In most societal analyses, an important part of the output is discussion of assumptions, rationales, and critical considerations on which the forecasts are based.

Level of Detail

There are no inherent limits. Pattern recognition techniques can be applied to the smallest scale events or to the rise and fall of civilizations.

Level of Confidence

In general, these techniques do not produce results of high confidence because they customarily deal with "grey" areas involving many human intangibles. Exceptions occur, however, when the data are simply and directly tied to the forecast. Thus the precursor event of births this year confidently indicates much about the number of 1-year-olds next year. Results obtained with Box-Jenkins or Normex are usually more accurate than those obtainable by less complex methods.

Communicability of Results

Because these methods tend to be used in obscure situations characterized by nonevident interrelationships, results are often hard to communicate fully. Moreover, special interest groups tend to see in social statistics what they prefer to see, and not necessarily what the analysis suggests. Similarly, results obtained via such rather technical methods as Normex or Box-Jenkins tend to be more difficult to grasp than those from simpler extrapolatory techniques.

Credibility of Results

What is said above under "Communicability of Results" also applies here. Anything difficult to understand and subject to diverse interpretation usually is far from credible to critics, even though the results may be derived with the greatest care.

Span of Forecasts

In general, forecasts based on pattern identification are near- to midterm. There are a few exceptions. Demographic "precursor" forecasts can be made for considerable periods ahead. Even more spectacular is the ability of astronomers to forecast the appearance of comets for centuries ahead. But few human affairs repeat themselves with such regularity.

Resources Needed

Essentially all important pattern identification techniques are time-consuming and costly. The statistical methods require extensive computer manipulation and high levels of mathematical skills. The less rigorous social methods often require collection of hard-to-obtain data, elaborate model building and testing, and a good deal of consultation with experts in diverse fields.

Procedures

The initial "flash of genius" in which the pattern underlying events is grasped is an art well developed by many planners. There is no substitute for this art; very often the most learned scholar in a field is less adept at hitting on the structuring, explanatory insight than the planner who approaches the problem afresh. In contrast, the procedures required to test the validity and comprehensiveness of the pattern and to develop it into a defensible forecast often require specialized knowledge the planner should properly seek from consultants rather than try to develop as an individual. Techniques such as Box-Jenkins require much mathematical expertise; Normex calls for less, but even so it is beyond the statistical powers of many planners.

Case Examples

Box-Jenkins

Because the procedures of Box-Jenkins are so complex, no attempt is made here to explain them operationally. In general, the method is pursued in three main stages, as shown in Figure 4.

The diagram shows the basic steps in applying this method as developed by Professors Box and Jenkins. The originators of the method have postulated a general set of models from which one is selected as the initial case in Stage 1. In Stage 2 this model is applied to the available data and a determination is made as to whether the model is adequate. If it is not adequate, the model is either modified or a new model specified and Stage 2 repeated. After a number of iterations, an adequate model is produced and the forecast is actually generated in Stage 3. If the forecast is to be used for control purposes, a control algorithm may be generated.

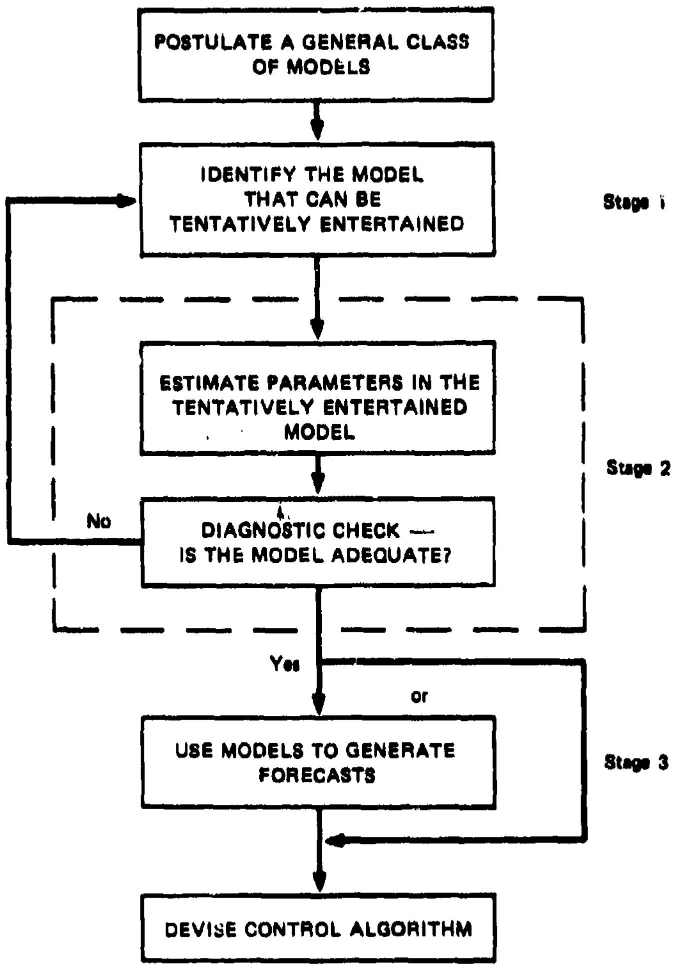


FIGURE 4 BOX-JENKINS METHOD

Those wishing to use the Box-Jenkins method may wish to examine the "automatic Box-Jenkins modeling program" offered by Automatic Forecasting Systems, P.O. Box 563, Hatboro, Pennsylvania 19040.

Normex

The Normex procedure, being a good less complex mathematically than Box-Jenkins, will probably be more useful as part of the do-it-yourself kit of planners.

Forecasting the recreational requirements at a prospective Corps reservoir is a commonly encountered problem.* A closely related problem is forecasting the distribution of that attendance among several kinds of recreational facilities. Solely for the purpose of explaining the mathematical procedure, the following example describes the application of the Normex technique to the problem of forecasting the distribution of total attendance among recreational activities at Corps reservoirs. Such a forecast is useful as a basis for planning for and allocating recreational investment among several kinds of recreational facilities to provide an optimum match to anticipated user preferences.

The five steps involved in making a Normex forecast of attendance distribution are:

(1) Assemble historical data on Corps reservoirs and on cultural changes that contribute to changes in the use of recreational facilities. Tabulate important changes and project.

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*IWR Research Report 74-1, June 1974, "Plan Formulation and Evaluation Studies--Recreation," presents one method for forecasting initial attendance, based on a comparison between the prospective reservoir and attendance at existing Corps reservoirs that are most similar in selected physical characteristics.

(2) For selected years, draw histograms of the frequency distributions of the attendance factors. Plot the data.

(3) For each of the histograms, construct cumulative frequency plots on lognormal probability paper. Graphically estimate the mean and standard deviation of the underlying normal distribution.

(4) Plot values of the mean and standard deviation of the underlying normal distributions as determined for the selected years versus time, and extrapolate to the future date of interest.

(5) Using the extrapolated values obtained in Step 4, along with projected values of future use of facilities obtained in Step 1, forecast the cumulative distributions for recreational facilities.

To apply this procedure large amounts of data concerning existing reservoirs must be collected and organized. Pertinent data from Corps reservoirs would have to be updated to include actual use of specific recreational facilities by type. For the sake of simplicity and clarity the following limitations and assumptions in the example are noted:

- The data available for such an analysis are at present limited and fragmentary. Accordingly, the data used herein are entirely hypothetical.
- A planning lead time of five years is assumed for the availability of facilities. Thus the target date for the forecast is 1980.
- An actual application would require forecasts for each type of recreational activity. This example will treat only one type of activity.

Having observed (via leading indicators, life ways, or some other type of forecast) a growing need for water-related facilities, the planner would first collect and then analyze all data indicating the use of various different types of recreational activities. For the sake of this example, we will assume s/he has observed an increase in the use of swimming facilities. Moreover, demographic data indicate a large population growth in the age brackets most likely to use swimming facilities, as well as a shift in values of the retirement age population toward increased use of swimming-related recreation. The historical attendance distribution for Corps reservoirs by ratio of swimmers to total attendance is shown in Table 14 for 1960, 1965, and 1970. In order to derive the distribution of swimming facilities required in a particular forecasted year, the mean and standard deviation for the previous year's use of facilities are estimated graphically.* Histograms and cumulative frequency distribution charts for facility use in 1960, 1965, and 1970 are illustrated in Figures 5 and 6, respectively.

The values for the mean and standard deviation obtained from the cumulative frequency distribution charts are then plotted versus time and extrapolated (by simple eye-balling) to 1980 (see

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*These values can also be calculated using the following equations. Note, for this example the X values refer to the logs of the observations.

$$\bar{X} = \sum \frac{x_i}{n} \qquad \text{Standard deviation (SD)} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n}}{n - 1}}$$

Table 14

HISTORICAL DISTRIBUTION OF FACILITY USE AT RESERVOIRS*

Ratio of Swimmers to Total Attendance	1960			1965			1970		
	Number	Percent	Cumulative Percent	Number	Percent	Cumulative Percent	Number	Percent	Cumulative Percent
0.10	3	6%	6%	3	6%	6%	2	3%	3%
0.15	42	81	87	10	19	25	5	10	13
0.20	5	10	97	31	60	85	10	19	32
0.25	2	3	100	5	10	95	18	34	66
0.30				3	5	100	5	10	76
0.35							5	10	86
0.40							4	8	94
0.45							3	6	100
Total	52	100%	--%	52	100%	--%	52	100%	--%

*From Table 14, we see that, in 1960, 81 percent of the reservoirs had a swimmer to total attendance ratio of 0.15, i.e., 15 percent of the attendees were swimmers. By 1970, we see the demand for swimming facilities has grown 25 percent at 34 percent of the facilities. Note, also that at 6 percent of the reservoirs 45 percent of the attendees used swimming facilities.

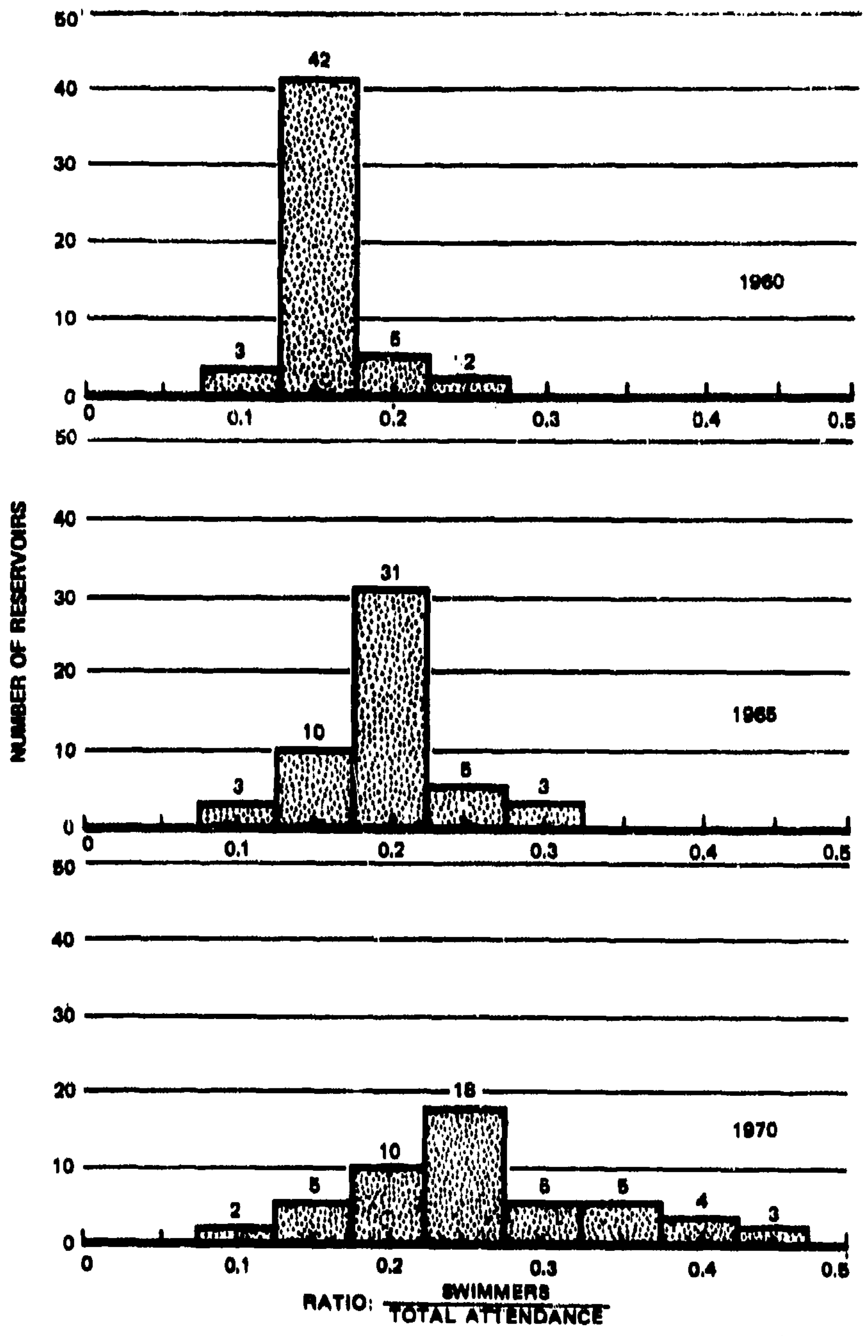


FIGURE 5 DISTRIBUTION OF SWIMMERS AT RESERVOIRS

To devise Figure 6, the cumulative percents (Σ%) from Table 14 are plotted for the selected years on probability paper. The mean and standard deviation are then estimated graphically. For this lognormal distribution,

$$\text{mean} = \ell n\ X_{50\%}$$

$$\text{standard deviation} = \ell n\ \frac{X_{85\%}}{X_{50\%}}$$

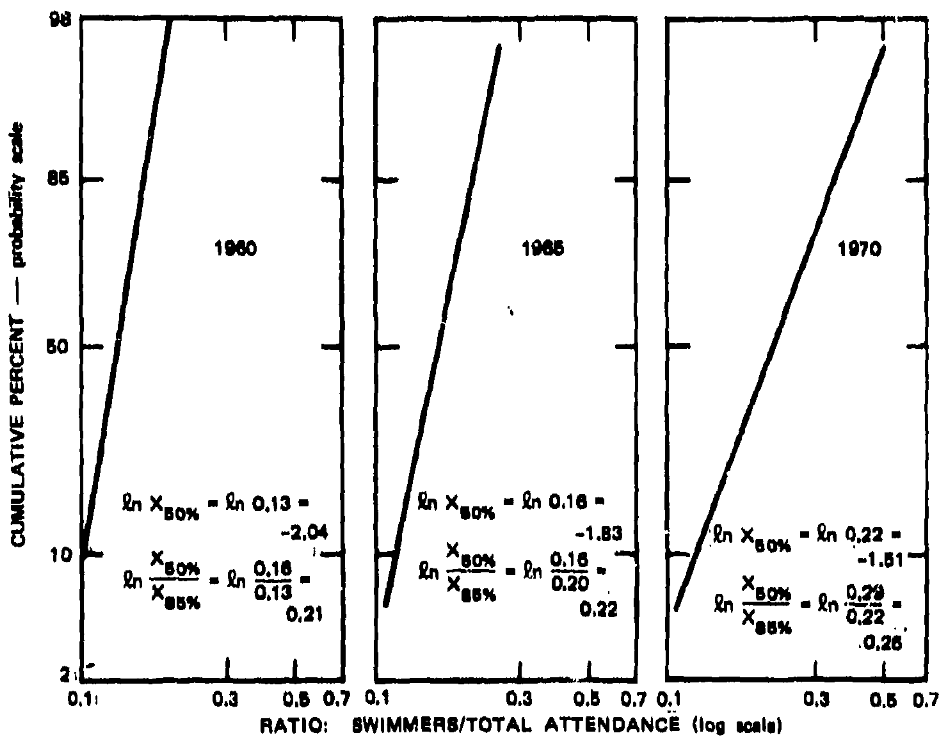


FIGURE 6 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR SELECTED YEARS

Figures 7 and 8). Using the extrapolated values from Figures 7 and 8, cumulative distributions can be plotted for each forecasted year. For some future year, say 1980, the cumulative distribution for swimming facilities is forecasted. This is done by plotting the mean and the standard deviation on log probability paper as shown in Figure 9. Using this projected distribution one can, for example, read that 80 percent of the 1980 demand will be for a ratio of 0.5 or less, and 20 percent of demand will be for a ratio of more than 0.5. This means that in designing facilities for 80 percent of the 1980 demand half the total attendees will want swimming facilities. To design for peak loads, note that at 10 percent of the reservoirs 60 percent or more of the total attendees will want swimming facilities. Figure 10 shows a histogram of this distribution.

The normative aspect of the foregoing procedure could be enlarged by including data on attitudes, leisure preferences in each

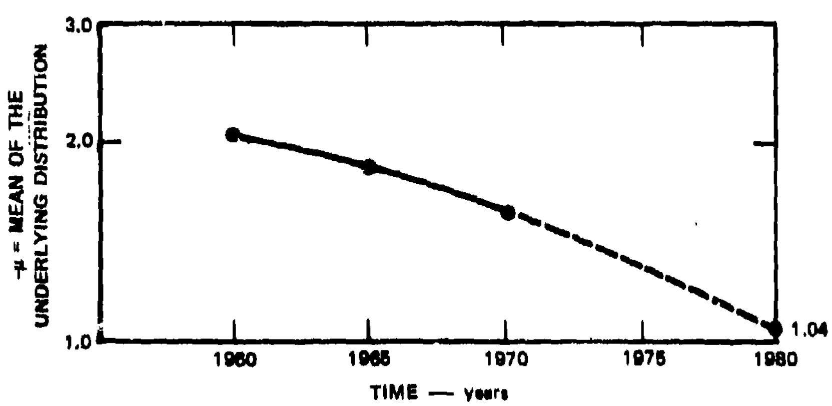


*Figure 7 is arrived at by plotting the mean and the standard deviation for each of the selected years. For example, read the mean value of X that corresponds to the 50 percent value on the probability scale (Figure 6) and then plot the log of X.

FIGURE 7 EXTRAPOLATION OF THE MEAN*

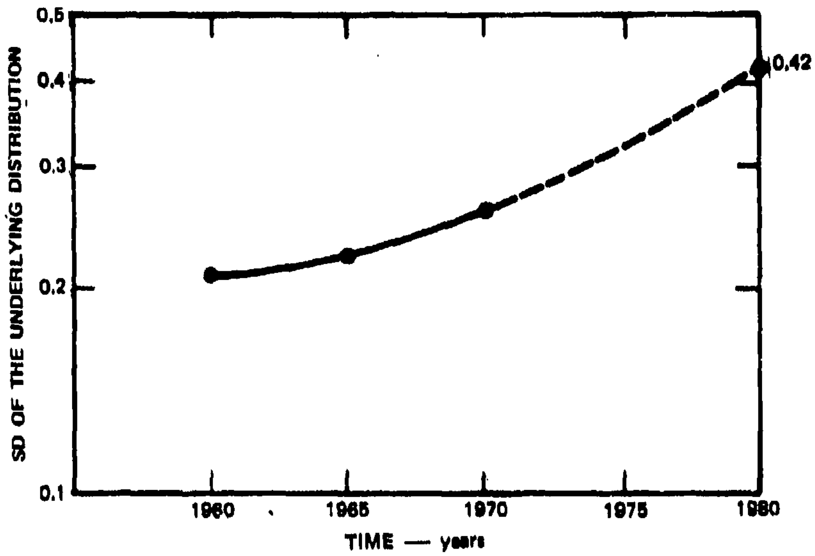


FIGURE 8 EXTRAPOLATION OF THE STANDARD DEVIATION

reservoir area, life styles, changing family norms, and so forth. The further addition of attendance distribution and trends among recreational activities would provide the planner with a broader basis for selecting "most similar" existing reservoirs and increase the level of confidence in forecasting the recreation potential of a reservoir under study.

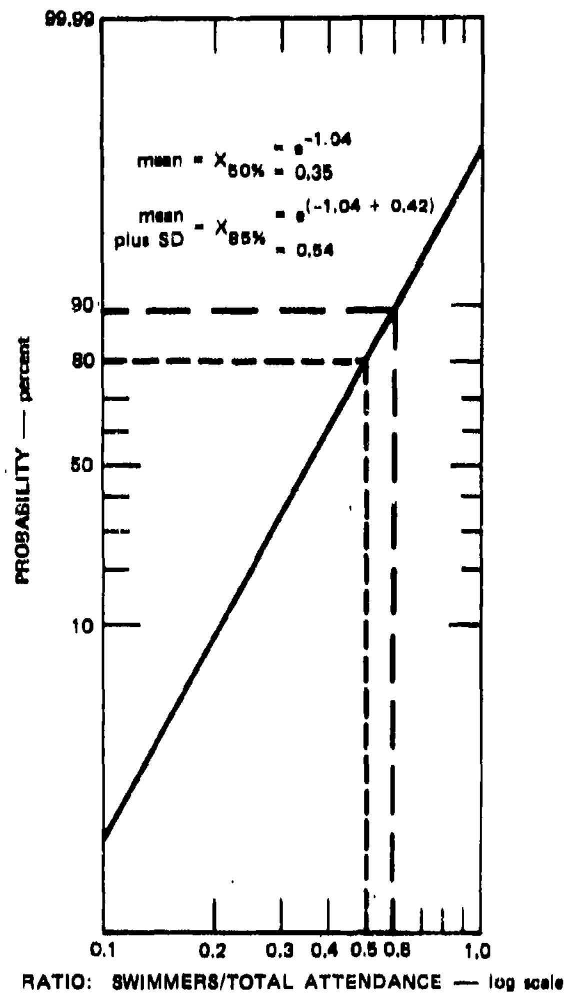
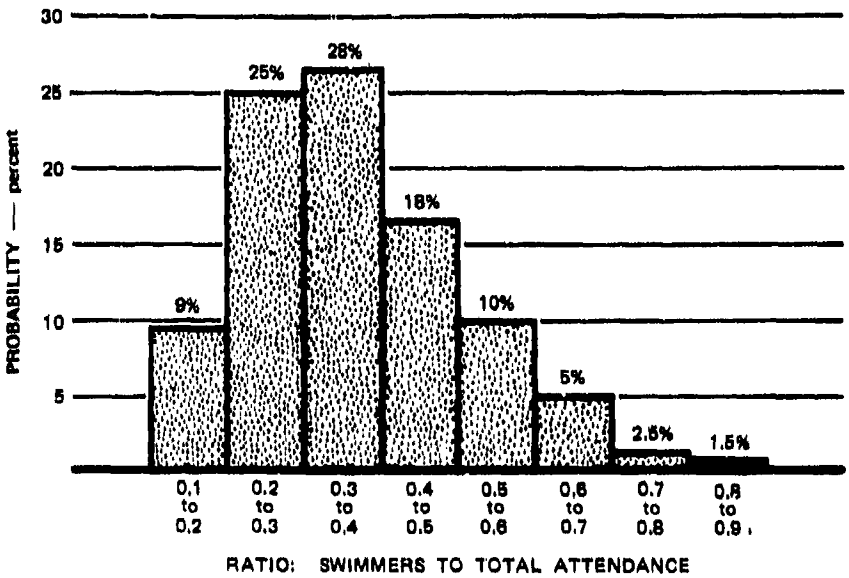


FIGURE 9 FORECASTED CUMULATIVE DISTRIBUTION, 1980



For each ratio, 0.1, 0.2, 0.3, etc. read the corresponding height (probability percent) from Figure 9. The difference between each consecutive ratio pair gives the height of the respective column.

For example:

	Ratio		Height
	0.6	=	90%
	0.5	=	80%
∴	0.5 to 0.6	=	10%

FIGURE 10 HISTOGRAM OF 1980 FORECASTED DISTRIBUTION

PROBABILISTIC FORECASTING

General Description

Abstract

Many phenomena for which forecasts are needed appear to change randomly within limits. Probabilistic forecasting methods use mathematical models of such phenomena. Numerical odds are assigned to every possible outcome or combination of outcomes. On the basis of such assigned odds, predictive statements are made about the future behavior of the phenomenon studied. Probabilistic forecasts are helpful in discovering where, how, and when a phenomenon may best be anticipated in the future, and where nonpredictable occurrences must be accepted. Such methods should not be used where adequate mathematical models cannot be developed, or when the results must be understood and accepted by decision makers untrained in these specialized techniques.

Definition

Probabilistic forecasting involves the development, testing, and use of mathematical stochastic models to predict the future behavior of phenomena that are presumed to behave in a random manner. "Stochastic" refers to any phenomenon that obeys no discernible cause-effect relationships but that nonetheless varies within limits. Numbers resulting from the roll of dice are an example.

There are many probabilistic methods. Several of the best-known are briefly described below.

Point and Interval Estimation--Here, we estimate the probability of various outcomes for a single event. For example, what is the probability that a river will reach various maximum annual water levels?

Monte-Carlo Simulation--In using this method, we define a process of interest as consisting of a set of possible events. Then, invoking a process analogous to roulette, we go through many rounds in which various combinations of possible events are thrown out at random. By keeping careful track of the various combinations, we are able to estimate relative probabilities and so to make at least some predictions about future outcomes. The technique has been applied to estimate the probability of rainfall or of flood.

Markov Processes--This method assumes that events are ordered in chains (Markov chains). A corollary assumption is that there is some estimable probability that a given event will be succeeded by another given event. This is called the transition probability. The method also assumes that the amount of time required to make the transition from one event to its successor may vary, and that the probabilities of this transition time can be estimated. From this flows the final estimate, namely the long-run probability that the process will be in any given state as defined by events. The method is applicable, for example, in estimating demand at a recreational facility, river traffic, and all kinds of arrival and servicing problems.

Non-Markov Processes--Markov processes begin by assuming a certain event and go on to estimate what could happen next. Non-Markov processes make a different assumption about chains of events. The non-Markov assumption is that subsequent transition probabilities are dependent on previous transition probabilities. This approach, for example, offers a means of reassessing the prospects for building a bridge given new priorities among interested parties.

Parametric Sensitivity Analysis (PSA)--Any process or project proposal can be defined as a series of inputs--men, money, materials, technology, and so on. PSA offers a means by which the relative importance of each input can be estimated. Depending on the situation, no matter how much an input may vary, its impact on the ultimate outcome may be crucial, moderate, or trivial. After PSA has identified those inputs whose impact must be trivial no matter how widely they may vary, such inputs can be treated as deterministic constants. This approach permits the forecaster to concentrate his attention on those inputs known to be crucial to the ultimate outcome. PSA is useful in all sorts of design problems in which some key parameter is expected to change. These range from design of recreational facilities to organizational structures.

Inventory Theory--In many situations--for example, in warehouse management or in capital budget forecasting--it is necessary to estimate when replacements will be needed, how many will be needed, and how much time will intervene between placing an order and receiving it. Inventory theory affords a framework of concepts and procedures by which such estimates can be made probabilistically. The approach applies to intangibles, such as maintenance schedules, as well as to the inventory of supplies.

Queueing Theory--In a supermarket, a bank, or a construction project staging area, lines of customers, equipment, or material arrive at critical points for service, handling, or processing. In designing service, handling, or processing facilities it is essential to estimate how often how many inputs will arrive, and how long it will take to handle an input. Queueing theory provides statistical methods for making such estimates. The theory also enables one to forecast what effects would be felt if the number of service channels were increased or decreased at a given point, or if any one of various policies were used to determine which inputs should receive attention first.

Decision Analysis--This is the best-known probability technique. By combining aspects of systems analysis and statistical decision theory, the method builds a "decision tree" aimed at showing the user how to approach a complex, dynamic, and uncertain situation in a logical manner. The tree permits mathematical modeling of the decision, and quantitative evaluation of the various action options.

Risk Analysis--This is best known for its applications in the space program. Such programs deal with extremely large, extremely complex, one-of-a-kind systems. Furthermore, because of their size and complexity such systems cannot be made in multiple copies, and success in their one-time-only operation is vitally important.

Where such unusual situations demand and justify it, risk analysis can be uniquely helpful. Two basic approaches are used, the "event tree" and the "fault tree" approach. The event tree approach is sequence dependent. First, building a complex symbolic mathematical map of the system, an "initiating event" is selected for study. Statistical analysis procedures are then invoked to estimate the failure probabilities of various protective devices or dependent components for each alternative event path. The fault tree is an analogous but somewhat more complex approach. Beginning with a given fault, the probabilities and consequences of subsequent impacts on the total system can be predicted. Because of its rigor, complexity, and cost, risk analysis is justifiable only in relatively high-cost, high-risk, high-reliability projects, and not always then. The method is applicable only if the system studied can be completely and rigorously specified. Examples of Corps use might be control gates and levees for flood control or, more obviously, the chain of sensors, switches, breakers, power sources, and the like, for spillway gates and hydro-generator systems.

Optimization Methods--These are increasingly used in project and program planning management. Simply stated, optimization seeks to secure the most desired results with the fewest undesirable consequences and the least expenditure of resources and effort. While optimization is perhaps more a planning and management tool than a forecasting tool, it clearly can be used for forecasting purposes. To use the approach, one specifies the desired outcome (the normative future, a forecaster would call it). Then every possible combination of alternatives is identified through which the desired outcome might be attained. Finally, all alternatives are assessed against each other to determine which should be most effective, as measured against some set of performance criteria. This method could be applied to design recreational facilities to serve a specified number of people at minimum cost or to select the optimum sequence of steps for achieving a given water quality in a stream.

Assumptions

In using probabilistic and related methods, it is assumed that:

- The phenomenon of interest can be described or defined in terms of associated events.
- Every event considered has a discrete, definable outcome.
- Logical procedures plus a knowledge of inherent structures and limits can be applied to estimate the likelihood of every possible outcome.
- Increased or improved estimates of possible outcomes can be translated into predictions about the future states or behavior of the phenomenon with which the events studied are associated.

History

Basic knowledge and use of probabilistic forecasting methods can be traced to ancient times. In the contemporary technical sense, most of the methods mentioned and discussed here have their origins in the World War II period, and especially in operations research. Risk analysis and optimization are more recent offshoots, stemming from the increasing use of digital computers and such technological efforts as weapons development and the space program.

Main Uses

Two basic postures can be taken toward the future, acceptance and mastery. By accepting what is inevitable ahead of time, we can accommodate ourselves to it as much as possible. By controlling what can be controlled, we can work toward attainment of desired outcomes.

In most cases, some mixture of both postures is necessary. While we cannot shape the future exactly and always to our aspirations, neither are we often totally the captive of blind fate. The difficulty is to figure out in each situation what is and is not likely to happen, so that we can come up with the best mix of acceptance-mastery strategies.

It is in this situation that probabilistic methods are most helpful. If their end products are less than certain, they are more than nothing at all. Oftentimes, a knowledge of the odds is in itself enough to enable us to have our way. The Apollo program was possible and successful because probabilistic forecasting enabled us to assess risks and make investments accordingly.

Limits and Cautions

It is quick, simple, and inexpensive to resolve a forecast by tossing a coin. At the other extreme, millions of dollars and many highly skilled person-years of efforts may be invested in a risk analysis project. In considering the use of probabilistic forecasting methods, we must be sure that the method considered is adequate and appropriate for the task at hand.

The costs and other requirements for probabilistic forecasting rise rapidly with complexity. Such being the case, users are well advised to begin by making rapid, rough approximation estimates. Often, the results from such quick-and-dirty procedures will be almost as useful as the outcomes of far more elaborate efforts. In any case, first-pass estimates should shed more light on the nature of the forecasting challenge, which in turn will provide guidance as to which of the more sophisticated methods available is most appropriate.

Other Techniques

Many other forecasting methods (especially Trend Extrapolation) may be used in place of probabilistic approaches, depending on the particular situation. In cases where numerical estimates are impossible or of dubious validity, the qualitative methods described in this Handbook are useful.

Product or Result

Because the number and variety of these methods is great, the end product may take many forms: for instance, sets of probability matrices, decision trees, fault trees, interactive computer models.

Level of Detail

The elements used in reaching probabilistic conclusions are often exceedingly detailed. Some decision trees, for example, require hundreds of separate units. In contrast, the "answers" yielded by these methods typically are simple ranges of probability.

Level of Confidence

Probabilistic methods are typically used where the number of possible outcomes is large, and the probability of any given outcome is contingent on many factors. By the very nature of the topics to which they are applied, probabilistic forecasts are apt to command only limited confidence. Fortunately, such methods normally use built-in statistical measures of uncertainty. Persons trained in such methods usually can agree on the validity of confidence measures. When the application of such measures suggests the reliability of a study and when a few among many outcomes seem much more certain than the others, then a generally high level of confidence may be enjoyed by a probabilistic forecast. Unfortunately, such cases are not typical.

Communicability of Results

Most probabilistic methods used in contemporary futures forecasting are relatively sophisticated and technical. The results of such forecasts may be incomprehensible to persons inexperienced with the particular technique. The significance of probabilistic forecasts will certainly be lost on persons who lack a basic grasp of statistical and probabilistic concepts.

Credibility of Results

Credibility and communicability are intimately related. Few people who have something at stake are likely to accept as credible that which they cannot comprehend. As mentioned above, a typical probabilistic forecast may be difficult to communicate to persons not trained in such methods. For that reason, the most sophisticated probabilistic forecasts are probably limited to exchange among professionals. It then becomes their task to provide credible interpretations to their respective clienteles.

Span of Forecasts

Not every probabilistic forecast is placed in a specific framework. Risk analyses, for example, provide sequential forecasts not tied to any particular date. When specific time spans are involved, their location and duration will be determined by the intended uses of the forecast. Many NASA Apollo forecasts, for example, were based on normative target dates for missions--dates often set years in advance.

Resources Needed

For probabilistic forecasts of any scope or sophistication, at least one appropriately trained and experienced person is essential. In actual fact, a few person-weeks to a few person-years time may be required, spread over a period of weeks or months, and often involving extensive use of computer facilities. Accordingly, even minimum-effort forecasts may cost thousands of dollars, while more ambitious projects may well cost tens or even hundreds of thousands of dollars.

Procedures

Planners with a reasonable grasp of statistical mathematics will find most probabilistic procedures (such as queueing theory or decision analysis) easily within their powers. Unfortunately, some procedures, including risk analysis and aspects of Markov and non-Markov processes, are sufficiently specialized to require help from experts.

Case Example

Queueing Theory

The following example shows how queueing theory could be applied to forecast waiting time at canal locks. The purpose is to define lock systems of optimum utility for a given traffic situation. The data given in the example are hypothetical but, in general, accord with experience.

The procedure involves five steps, described below.

Demand--First the statistical probability distribution for demand on the system must be estimated. This distribution might depend on time of day or year.. A typical distribution is shown in Figure 11.

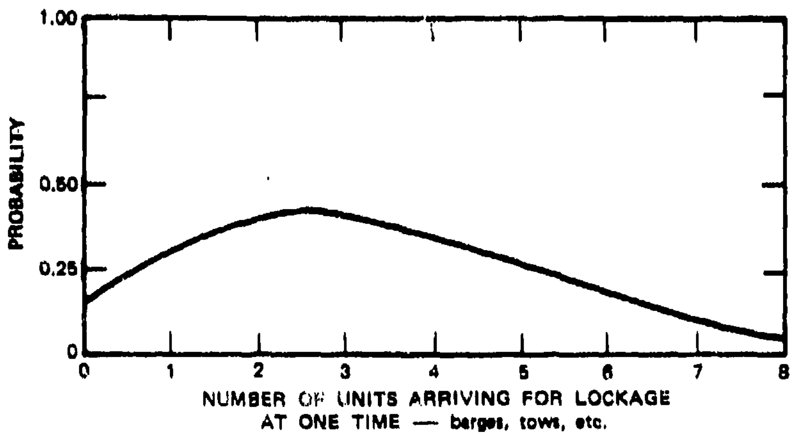


FIGURE 11 PROBABILITY DISTRIBUTION FOR DEMAND

Transit Time--Next, the statistical probability distribution for lock transit times for an individual unit for a particular type of lock must be estimated. Clearly, this estimate will require analyses of different types of locks, each type having special characteristics. Thus, there may be as many distributions as there are suitable lock types. Figure 12 illustrates hypothetical patterns for two types.

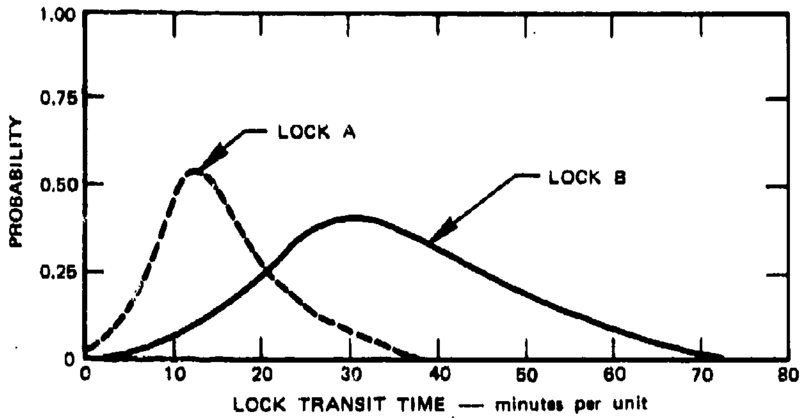


FIGURE 12 PROBABILITY DISTRIBUTION FOR TRANSIT TIMES

Queueing Equation--Queueing theory equations that use demand and lock-transit time statistical distributions such as those shown in Figures 11 and 12, are now obtained. These equations are generally found in operations research or queueing theory literature or can be derived by mathematicians. The example below assumes: a single lock, that the arrival times are distributed according to the Poisson distribution, and that the transit times are distributed according to the exponential distribution.

$$L = \frac{a}{\mu + a}$$

$$L_q = \frac{a^2}{\mu(\mu + a)}$$

$$W = \frac{1}{\mu + a}$$

$$W_q = \frac{a}{\mu(\mu - a)}$$

where: a = the average arrival rate (units/minute)

$1/\mu$ = the average transit time (minutes/unit)

(Note μ and a can be estimated from the statistical distribution shown in Figures 11 and 12.)

L = the expected line length (queue plus lock)

L_q = the expected queue length

W = expected waiting time including transit time

W_q = expected waiting time in the queue.

Other Concepts--Alternative system concepts can be compared on the basis of the calculations given in "Queueing Equation" above. Other calculations can be made relative to cost or, as illustrated in Figure 13, with respect to the probability of an arriving unit having to wait different times.

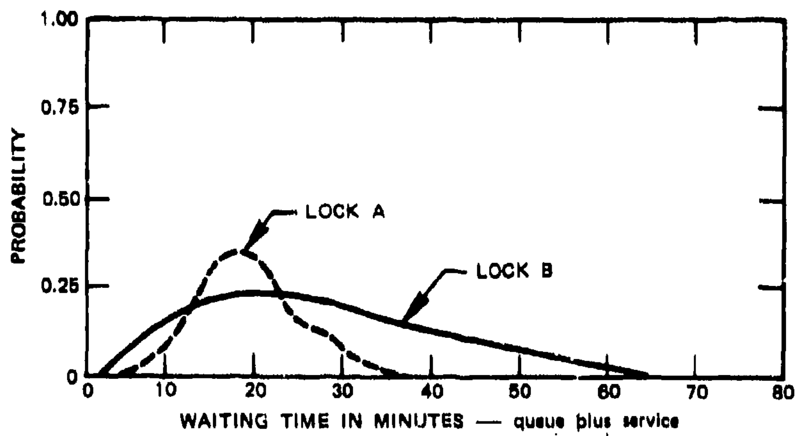


FIGURE 13 PROBABILITY DISTRIBUTION FOR WAITING TIMES

An example of a cost analysis might plot the expected waiting time (W) described in "Queueing Equation" for a number of alternative systems against system cost. This is shown in Figure 14.

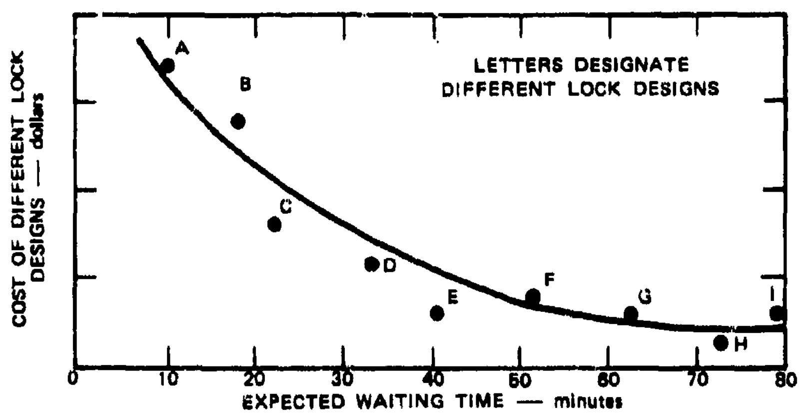


FIGURE 14 COST ANALYSIS OF WAITING TIMES

Optimum Design--On the basis of the foregoing analyses it is possible to specify the optimum system of locks as measured in total costs. This analysis could take the form shown in Figure 15.

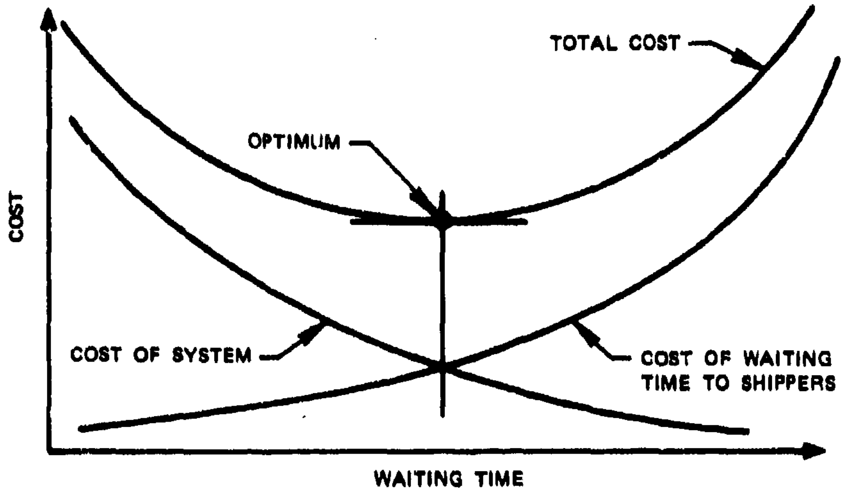


FIGURE 15 COST ANALYSIS OF OPTIMUM DESIGN

Section IV

FORECASTING TECHNIQUES USING MODELS AND SIMULATIONS

Introduction

This section of the Handbook discusses forecasting methods based upon models or simulations of the phenomena to be forecast. The specific techniques described are dynamic models, cross-impact analysis, KSIM, input-output analysis, and policy capture. As a group these can be referred to as structural models. Each can be used as a forecasting technique individually. In addition, three of the five can be used to provide specialty inputs to the others, as diagrammed below:

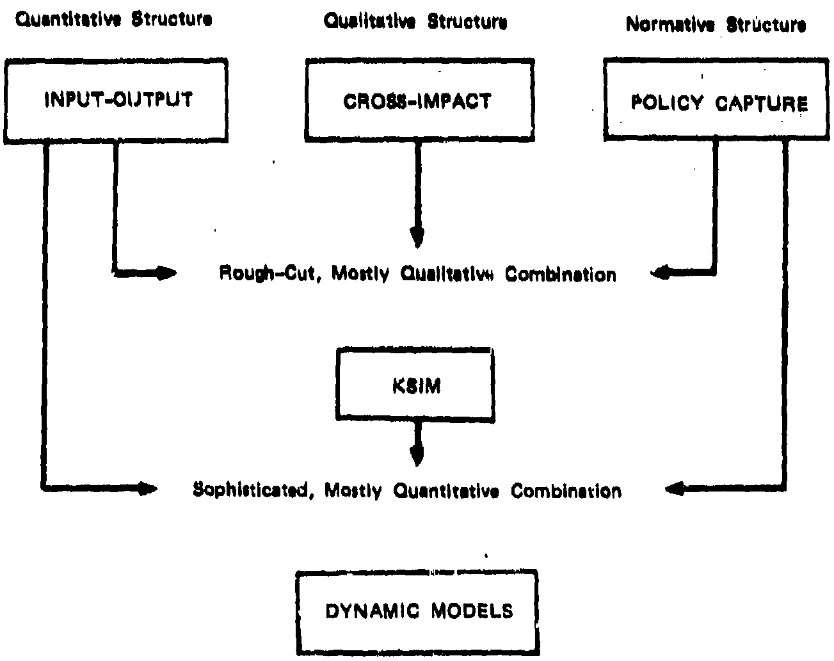


FIGURE 16 STRUCTURAL MODELS

Structural models are so called because they demonstrate the interactions of the separate elements of a system or problem, as well as their combined overall effect. Such models are helpful in attaining a broad perspective and a better grasp of the totality of a problem, in foreseeing effects that might otherwise be overlooked, and in anticipating (or forecasting) public reaction to alternative problem solutions.

Structural modeling can range in complexity and difficulty from an easily accomplished graphic display of the qualitative relationships among problem elements, to a comprehensive, formal dynamic model that deals with quantitative relationships over time and requires special skills and computerization.

The task of modeling a system begins with conceptualizing the system. The modeler first must establish the boundary of the system in both time and space. A useful tool for describing system structure is the feedback loop. Feedback loops provide a qualitative picture of the system structure. For some purposes, this structure must then be mapped into a quantitative or formal mathematical model. In order to quantify the model, specific numerical values are required for the parameters identified in the system structure. The system dynamics model builder places heavy reliance on experts in the field to supply these data.

The dynamics of a given system are produced by the action of feedback loops within the model. As presented by Anderson, Anderson, and Ferree (1972):

> A feedback loop traces qualitative cause-and-effect relationships from a given variable back to itself. For example, population, the stock of people in a system, is controlled by two rates, births per year and deaths per year. But these rates themselves depend on the population as shown in Figure [17].

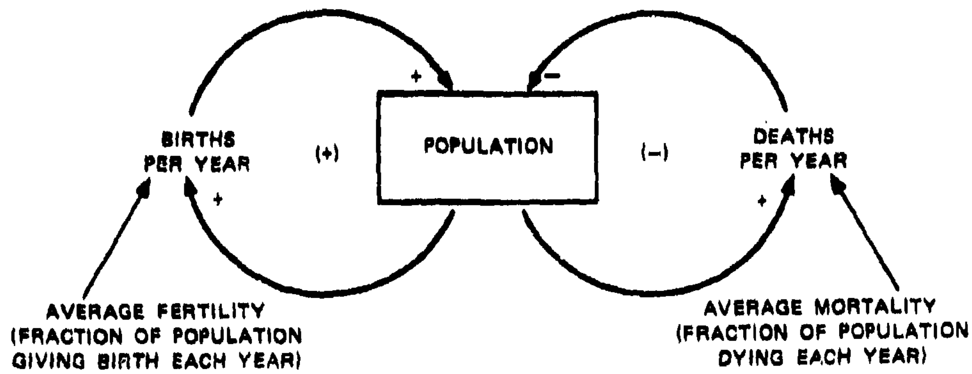


FIGURE 17 FEEDBACK LOOPS FOR POPULATION GROWTH

> For a given fertility (fraction of the population giving birth), more births make more population, and more population makes more births; the opposite is true for deaths. Hence, the population responds to the influences of a positive feedback loop and a negative feedback loop. If the positive feedback loop dominates (fertility is greater than mortality), then the population will grow exponentially without bound. If the negative feedback loop dominates, then the population will decline--ultimately to zero. The growth of capital follows the same pattern, but investment replaces births, and depreciation replaces deaths.

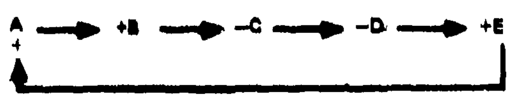
The exercise of constructing a model can be in itself valuable to a planner as an aid in anticipating the strengths, weaknesses, and consequences of possible solutions to a problem. Even qualitative structuring requires identification of the relevant problem elements, specification of the relationships (direct or inverse) between sequential problem elements, and tracing out the system structure, including its feedback loops. The resulting display is analogous to a block diagram of an electronic circuit. The following description outlines the procedure and conventions used.

<u>System Elements and Sequence</u>--All problem elements that have significant effects (symbolized here by letters) must be identified and arranged in the sequence of their interaction:*

<u>Qualitative Relationships</u>--These are indicated by a plus (+) at the head of the arrow for a direct cause-effect (that is, an increase in A causes an increase in B), or by a minus (-) for an inverse cause-effect (that is, an increase in A causes a decrease in B).

DIRECT: $\longrightarrow +$ INVERSE: $\longrightarrow -$

<u>Positive Loop</u>--A positive loop is one in which a change in one problem element is amplified by the feedback loop, and is identified as a loop containing either no inverse relationships (-) or an even number of inverse relationships:



The above loop is read as follows: As A increases B increases, as B increases C decreases, as C decreases D <u>increases</u>, as D increases E increases, as E increases A increases. Conversely, if A decreases, the loop effect is to further decrease A.

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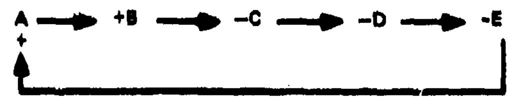
*The usual format is a curved and rounded conglomeration (see Figure 18, Feedback Loop Diagram for the New England Water Model, shown in the Case Example of this section).

Negative Loop--A negative loop is one in which a change in one problem element is attenuated, and is identified as a loop containing an odd number of inverse relationships:



The above loop is read as follows: as A increases B increases, as B increases C decreases, as C decreases D increases, as D increases E decreases, as E decreases A decreases.

In structuring the model, it is necessary to recognize that different cause-effect relationships may exist between problem elements. These relationships can be illustrated with loops, as in dynamic models, or in a matrix as in cross-impact and KSIM. For instance, some:

- Go in one direction only (e.g., precipitation causes runoff but runoff does not affect precipitation).
- Run in both directions (e.g., in the usual situation, environmental quality inhibits development and development degrades environmental quality).
- Are valid only between certain limits or may reverse beyond certain limits (e.g., quality of life may be enhanced by population increase up to some point and degraded by population increase beyond that point).
- Problem elements have no relationships, or at least none of consequence to the problem.
- Problem elements may have relationships to more than one other element and may therefore form a subsystem within the overall system.

DYNAMIC MODELS

General Description

Abstract

Dynamic models of complex, nonlinear systems are extremely useful for forecasting futures resulting from interacting events. The simulation model, which is usually numeric, reveals the evolution of systems through time under specified conditions of feedback. By changing equations or adding interacting trends, a large number of possible futures can be explored in computer runs. Dynamic models are also helpful in gaining qualitative insight into the interactions of system elements.

Among many applications, dynamic models have been used to suggest an overall framework whereby water supply and water quality can be related to broad considerations of population, employment, investment, and life style. The well-known Limits to Growth work utilized dynamic models. Dynamic models require extensive time, resources, and skills on the part of the developers.

Definition

A dynamic model is a formal model that allows the changes in system attributes to be derived as a function of time. The behavior of a dynamic system is generated within feedback loops.

Usually, numeric simulation methods are used to solve the problems posed by dynamic models. Basically, dynamic models consist of a number of reservoirs, or levels, interconnected by flow paths. The rates of flow are controlled by decision functions that depend upon conditions in the system. The levels represent the accumulation of various entities in the system. Rates are defined to represent the instantaneous flow to or from a level. Decision functions or, as they are also called, rate equations determine how the flow rates depend upon the levels.

Assumptions

A system dynamics model makes explicit assumptions about how decisions control, for example, the rate of flow of capital, resources, manpower, social goods, or any other entity specified in the model. These assumptions are stated in the form of decision variables, or rates, and must be formulated by mathematical equations indicating how the decision or rate depends upon the perceived state of the system at a given instant in time. A system dynamics model, thus, is primarily a representation of how the state of a system influences subsequent changes in the state of that system.

History

The dynamic modeling technique--known as system dynamics--was developed into its present form by Professor Jay Forrester and his co-workers at Massachusetts Institute of Technology in the early 1960s, following on earlier work by a variety of scholars. There have been several applications of the technique and numerous publications on it. Entire books either devoted to or based on the technique include: Industrial Dynamics (Forrester, 1961), Urban Dynamics (Forrester, 1967), World Dynamics (Forrester, 1971), Limits to Growth (Meadows et al., 1972). More recently, Mankind at the Turning Point (Mesarovic and Pestel, 1974) contains large elements of dynamic modeling. Many types of dynamic models have been utilized to analyze water resource problems.

Main Uses

A system dynamics model is used to assess the consequences of action taken within a system and to test the alternatives open to policy makers and planners. Because system dynamics is a simulation methodology, it is possible to test the sensitivity of the model to the parameters that quantify the model--that is, to assess how important a particular parameter is in the consequences that the model projects for the system. Sensitivity tests have two useful functions: first, they indicate where more research is needed to allow definitive assessments of the system's future; second, they indicate points in the structure of a system where a planning or policy change is most effective.

Aside from formal dynamic models that develop the quantitative interaction of system elements over time, the concept has great value for planning as a means for gaining insight into the interaction of system elements in a qualitative sense. To do this, it is merely necessary to identify the elements and graphically trace out the direct and inverse relationships. Such a diagram can serve as a communication tool that highlights desirable or undesirable effects, and can also point out relationships that should be examined with particular care.

Limits and Cautions

Clearly, no model of an involved social process can be complete. Indeed, no comprehensive theory exists for many subjects against which to test the model for completeness. Hence, there is always danger that the model omits critical factors or that relationships among factors are incorrectly hypothesized. Even if the model itself is sufficiently complete and sound, it is often difficult to provide a quantitative formulation for a decision variable or rate. The commitment of time and resources is significant. Feedback loops must be designated and each control factor specified. Equations must be developed for all rates and flows. Moreover, this methodology requires a large amount of data and an experienced model builder skilled in systems dynamics and simulation.

Other Techniques

System dynamics is one of the most developed forms of simulation for major systems. KSIM is often referred to as a poor man's system dynamics, but it does not offer the sophistication of the Forrester technique. Another simplified system dynamic procedure is QSIM (Wakeland, 1975).

Product or Result

The results of a dynamic model are a series of graphs illustrating the growth and decline of the system variables. The product presents the results of various alternatives as they compete for the defined resources.

Level of Detail

While the feedback loops in a dynamic model usually characterize broad concepts, such as water quality, the parameters involved in the definition of the water quality loop may be extremely detailed and include such entities as dissolved oxygen, required treatment, investment, and capital costs. The output display usually illustrates change in the levels of major variables, such as the level of dissolved oxygen attained for various treatment plant costs.

Level of Confidence

The validity of the model rests as much on the acceptance of its assumptions as on any quantitative test. Confidence levels can often be raised by showing how a model can successfully simulate the past. It perhaps should be noted that people sometimes become enamored of models and tend to forget the severe limitations under which any model of major social spheres must operate.

Communicability of Results

Dynamic models rely heavily on feedback loops to illustrate basic model structure. While these are usually good display devices, detailed models often require extensive examination and explanation to gain full understanding. The output graphics are presented in such a way as to facilitate assessment trade-offs between alternatives and are usually understood with ease.

Credibility of Results

The Forrester/Meadows dynamic modeling technique (used in Limits to Growth) is one of the most commented upon in the forecasting literature. Criticisms of it, although numerous and vehement, relate less to the theory of the model than to the specific selection or omission of factors in the model. Dynamic modeling is extremely popular and seems sure to be utilized to an increasing degree in the future.

Span of Forecasts

Dynamic models are designed to produce long-range forecasts. While most dynamic models simulate changes for at least 50 years, the technique can accommodate both longer and shorter forecast periods.

Resources Needed

Dynamic models usually require large amounts of data in tabular form. Often the extensive data requirements present problems and are time consuming. A team approach is recommended to develop a dynamic model. Because the interaction between modeler and field expert must be close in both the conceptual and data collection steps of model building, it is important for the two to work together throughout the modeling process. In this way the model's "client respondent" easily grows into the model's "user expert," and the model becomes an implementable practical tool rather than an isolated or sterile exercise. Unfortunately, the time requirement for developing such a model is great and thus it is not usually feasible for the decision maker to participate.

A computer is required to carry out the computations of the simulation. While a DYNAMO compiler is ideally suited for the simulation, it can be run on a more standard system, typically FORTRAN or BASIC.

In general, a minimum of six months is required to collect the data, develop the feedback loops, and test a dynamic model. Minimum costs are thus in the tens of thousands of dollars. Computer costs for running the simulation are small compared with the development costs.

Procedures

A planner not familiar with dynamic modeling would do well to enlist the aid of one experienced with the technique. The planner may very well be the principal architect of the model but he will need help in following conventions. If the model is to be quantitative, subject specialists will certainly have to be consulted to weight the various interacting loops.

Case Example

Dynamic Model of Water Resources

The New England Water Model (NEWM), as presented in IWR Paper 72-3, is used below to illustrate dynamic modeling in water resource planning. The generalized procedure for a dynamic model forecast consists of the following phases:

- Formulate the problem--boundaries, New England
- Identify system components--level of organization: highly aggregate
- Identify feedback loops--water quality and availability
- Quantify and validate--not illustrated
- Simulate future values
- Evaluate output

Formulate the Problem--In constructing a water resource model for New England, the important problems to be studied are the effects of:

- Urban-rural migration
- Changes in the economy toward services
- Allocation of water to recreation
- Pollution control policies.

Because this was an exploratory effort designed to introduce the concept of dynamic modeling, only the effect on pollution control policies is traced to an output stage. More specifically, the focus of the illustration is the cost effectiveness of alternative investment policies in meeting a desired water quality goal measured in tons of dissolved oxygen.

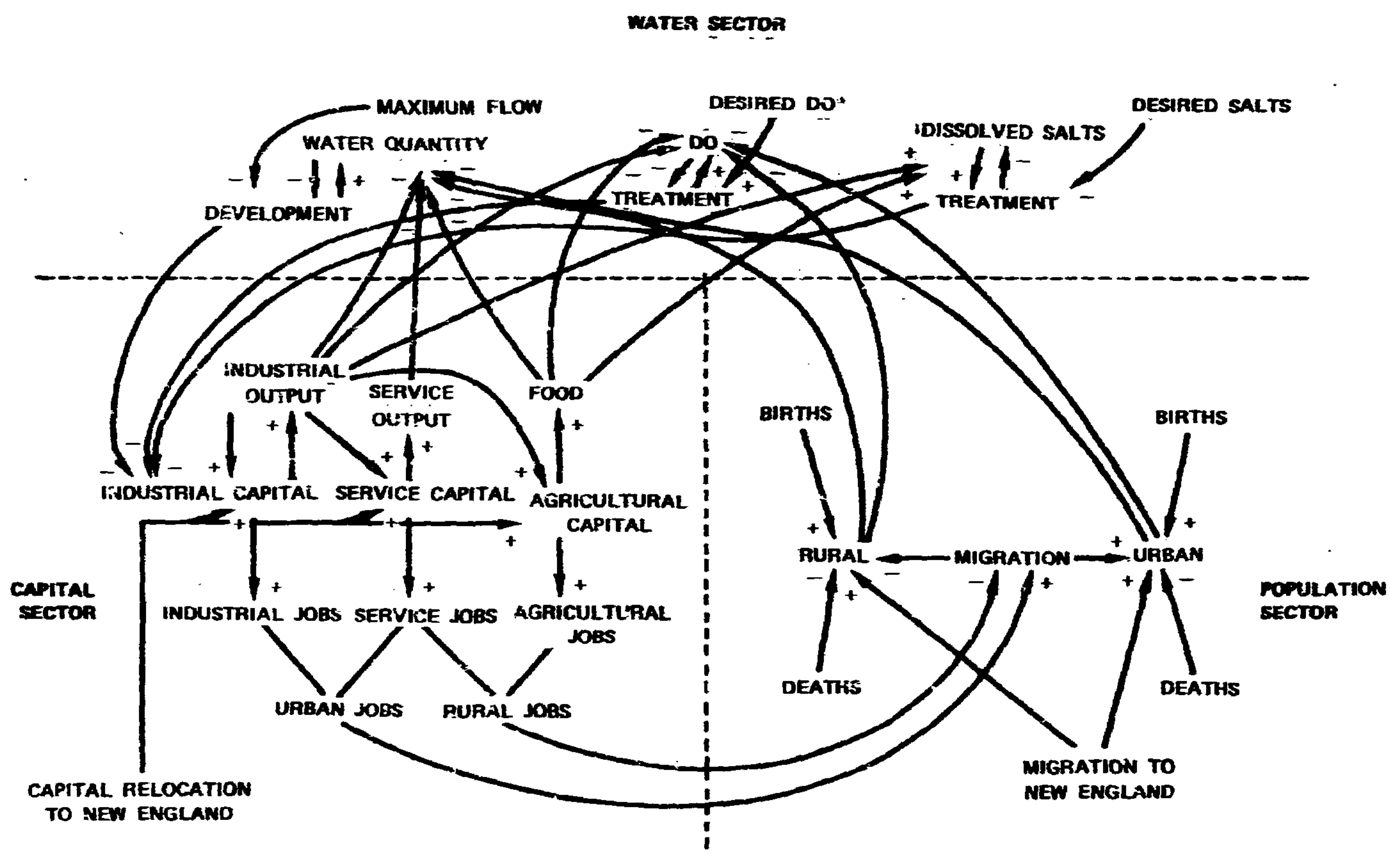
Identify System Components--The model is first disaggregated into three main sectors: capital, population, and water.

The capital sector, in turn, is disaggregated into three subsectors: industry, services, and agriculture. The demands of each for water and its associated pollution burdens are fed into the water sector. Similarly, the capital allocations for water quality and quantity are the response of the capital sector to the water sector. Examination of this feedback loop is an important facet of our study.

The population sector is divided into rural and urban subpopulations and is sensitive to both intra- and interregional migration. Migration is taken to be a function only of employment. To study the effect of other causes of migration, such as second homes, retirement homes, and so on, would require modification of this simplifying assumption.

The water sector includes the quantity of water available, as well as the pollution burden, both in dissolved oxygen and dissolved salts. In this sector, the effect of allocating pollution costs differently is examined, as well as the effect of setting standards for water quality. The development of new technologies and their impact can also be studied in this sector. The feedback loop diagram for system components is shown in Figure 18.

Identify Feedback Loops--An essential part of describing system structure is the feedback loop. The feedback loop traces qualitative cause and effect relationships from a given variable back to itself. There are two types of loops--positive and negative. Positive loops amplify while negative loops attenuate any change in the system.



*Dissolved Oxygen

FIGURE 18 FEEDBACK LOOP DIAGRAM FOR THE NEW ENGLAND WATER MODEL

Two interlocking feedback loops characterize this system, as shown in Figure 19. The water quality loop on the left attempts to raise the treatment level so as to achieve the goal of a desired

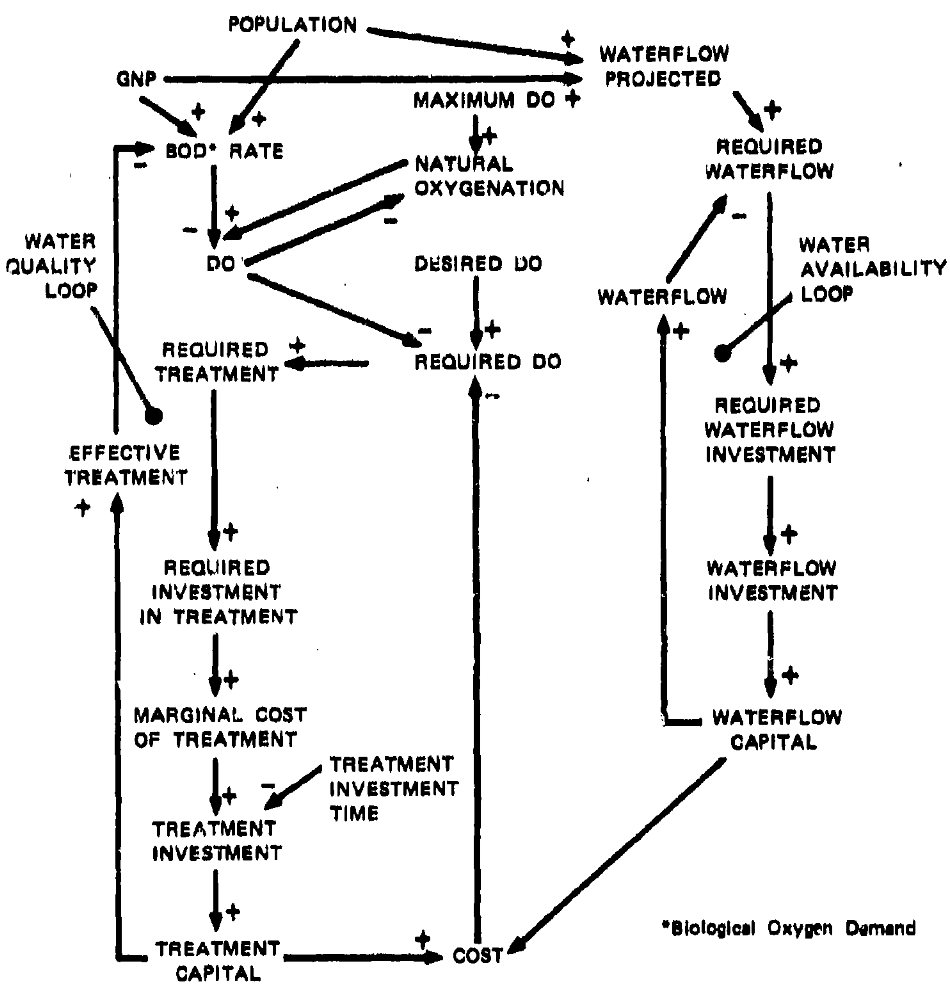


FIGURE 19 FEEDBACK LOOP DIAGRAM FOR WATER QUALITY AND WATER AVAILABILITY

dissolved oxygen. The water availability loop on the right attempts to develop new water sources to meet streamflow demands of industry and urban municipalities.

The water quality loop is a negative feedback loop,* as any change in required treatment will ultimately result in a change in the opposite direction in required dissolved oxygen (DO). Beginning with required DO we read: required DO causes an increase in required investment, which increases marginal cost, which increases treatment investment, and hence increases treatment capital. An increase in treatment capital produces more effective treatment, more effective treatment reduces the biological oxygen demand (BOD) rate, a lesser BOD rate increases DO, and increased DO reduces required DO.

Quantify and Validate--The qualitative determinations of feedback loops (Figures 18 and 19) a e in themselves valuable exercises to clarify interactions among several variables. In order to quantify the model, specific numerical values are required for the parameters in the system structure. This requires data such as were extracted from the North Atlantic Regional Framework Study for the New England Water Model and the use of experts in the subject matter. Following quantification, the experts are required to verify the model.

Simulate Future Values--Reference to the DYNAMO computer program used to simulate this system is made by Brown et al. (1974)

*Any loop that contains an odd number of inverse relations (-) is considered a negative feedback loop.

in Models and Methods Applicable to Corps of Engineers Urban Studies, U.S. Army Engineer Experiment Station, Vicksburg, Mississippi. The actual computer program is available for $5 plus postage from Jay Martin Anderson, Department of Chemistry, Bryn Mawr College, Bryn Mawr, Pa. 19010. (A note of caution: the program does not teach system dynamics and would be of little use without a basic understanding of system simulation.)

Evaluate Output--As an example of the output derived by applying this technique, the effect of different planning horizons on simulated results of a plan for water treatment and its costs are examined. Two cases were assumed: a case with a short-range planning horizon, and a case with a longer-range horizon for which BOD problems are anticipated. Thus, in the short-range case, BOD loads are anticipated for two years ahead; while for the longer-range horizon, BOD loads are anticipated for 10 years into the future. In each case, the treatment facility is planned to bring the respective BOD loads to a fixed standard. Figure 20 shows the two simulations. In Simulation B, the DO level easily exceeds the standard for desired DO, 5 mg/L, for most of the 60-year simulation; in Simulation A, however, the standard for DO is never achieved.* A difference between the costs is displayed, with the costs of Simulation A rising less rapidly because fewer future costs are internalized in the present. The interrelatedness among planning horizon, water quality standard, and cost are thus modeled so that the influence of changes can be explicitly examined. The

*This is primarily a result of the delay in bringing treatment facilities "on-line," which is represented in Figure 19 by the element, Treatment Investment Time.

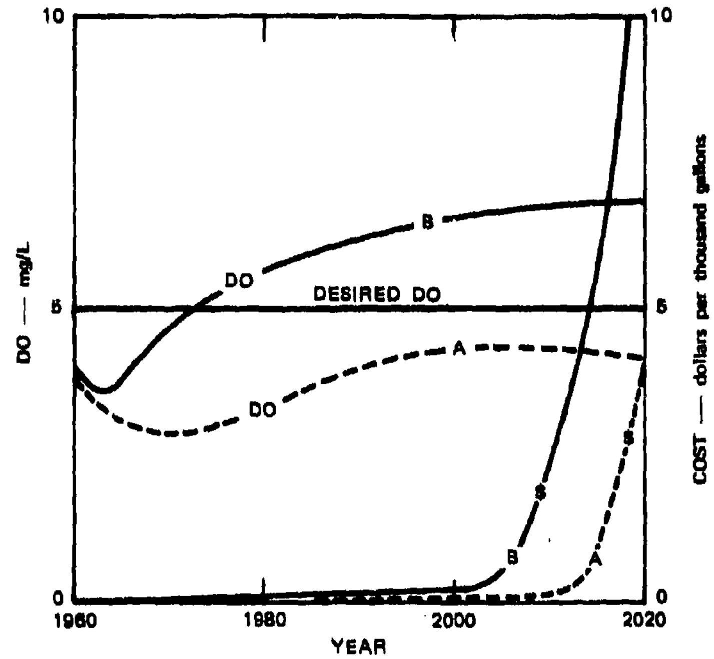


FIGURE 20 SIMULATION OF TREATMENT AND DEVELOPMENT COSTS OF WATER IN THE UNITED STATES AND DISSOLVED OXYGEN FROM 1960 TO 2020

optimum planning and investment costs to meet the desired DO level can be determined by running simulations between A and B.

The value of an extended planning horizon may seem obvious, but a systems dynamic model examining water quality in the Ohio River* indicated that water treatment facilities were constructed in response only to a delayed perception, much less a short-term projection of BOD loads.

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*J. E. Knight and W. W. Hines, "Complex Systems Analysis of Water Quality Dynamics: The Feedback Systems Structure," unpublished report to OWRR, Georgia Institute of Technology, 1970.

CROSS-IMPACT ANALYSIS

General Description

Abstract

Cross-impact analysis strives to identify interactions among events or developments by specifying how one event will influence the likelihood, timing, and mode of impact of another event in a different but associated field. Cross-impact analysis is used not only to probe primary and secondary effects of a specified event, but to improve forecasts and to generate single forecasts (or scenarios) from multiple forecasts. Cross-impact analysis is a basic forecasting tool helpful, if not essential, in most sophisticated forecasting. Every forecaster dealing with interacting trends should have an appreciation of the principles involved.

Definition

Cross-impact analysis is a systematic means of studying the interactions among events or developments. The analysis evaluates changes in likelihood of occurrence among an entire set of possible future events in light of limited changes in probability for some of the events in that set (Enzer, Boucher, Lazar, 1971). Thus, in using cross-impact analysis, experts strive to identify the few most important chains of events from among the many possible chains.

Assumptions

The underlying assumption is that a change in technology, social practices, values, or any other area will affect the surrounding environment in three ways. It will:

- Change the probability of occurrence of interconnected events.
- Change the timing of interconnected events.
- Affect the mode of impact of interconnected events.

The analysis is based on the ability of subject specialists to derive subjective estimates of the probability of occurrence of future developments in a given time period.

History

The cross-impact method had its origin in "Future," a simple simulation game invented by Theodore Gordon and Olaf Helmer in the mid-1960s (Gordon, Hayward, 1965). By 1968, a computer-based approach had been designed to consider explicitly the interconnections among events. The method has found widespread use in technological as well as social forecasting. Perhaps the most advanced cross-impact analyses have been carried out by such groups as the Institute for the Future, Monsanto, and The Futures Group. Applications include: Minuteman missile deployment, alternative future environments for education, long-range corporate planning, technology assessments of electric automobiles, and many more.

Main Uses

The main use of the method is to describe and quantify the impact of one development upon others. Most frequently the technique is used to "identify" which events are likely to be most important to some aspect of the future and how these events are likely to interact. Cross-impact analysis is often used to compare the implications of differing forecasts in a given field and to combine separate forecasts in discrete but allied fields into a single forecast.

Results have been used to define primary and secondary effects of a change (or a forecasted change) in one area upon: social trends, new or altered social demands, institutional functions (such as, personnel, production, distribution), developments in urban services, highways, recreation areas, management policies, R&D decisions, and similar areas. The technique provides insight into trade-off options and is useful in testing the consequences of various policy actions. By clarifying the critical events underlying possible future developments, the method helps to identify the contingencies of future proposed programs. Computerized runs of cross-impact matrices establish better estimates of the probability of occurrence of individual events, facilitate tests of the most effective responses under various circumstances, and point to the key events to be monitored.

Limits and Cautions

Cross-impact analyses cannot allow for events not included in the matrix. Therefore, defective or inadequate models of interacting elements can yield misleading results. Two other problems are evident. First, assignment of probabilities of interactions are subject to much uncertainty, especially in areas whose origin and anatomy are not clear. Examples include such "soft" trends as alienation, changing priorities and values, political disruption, or crime. Second, it is important to bear in mind that results are probabilistic, not certain occurrences. Indeed, high-probability events in the real world occasionally fail to occur and low-probability events will occasionally occur.

Other Techniques

Intuitively, participants in brainstorming, scenario writing, pattern recognition, and Delphi forecasting make use of cross-impact analysis, although not necessarily in a focused or systematic fashion. The technique is used as part of such forecasting methods as feedback analysis, decision analysis, and relevance trees. It is a central element in interactive simulation techniques of forecasting, such as Forrester-type dynamic models or KSIM. Trend impact analysis is a further development in impact analysis and is particularly useful in coupling existing trends with a range of possible future scenarios (Gordon, Becker, Gerjuoy, undated). Corps planners may associate this technique with impact assessment.

Product or Result

The main output is a table or series of tables showing interactions among items. Major studies may include numerous computer runs showing one-to-one interactions using a variety of assumptions; interactions among events, or among subdivided events. Very often interactions identified on a matrix are strung together on a time basis to create a scenario.

Level of Detail

Results can be detailed or gross, depending upon the subject being forecast and the elements taken into account in the cross-impact matrix.

Level of Confidence

For the most part, results from cross-impact analyses tend to be speculative. The reason is that the technique is selected chiefly in areas where interrelationships are unclear. Simple circumstances, such as the impact of births in one year on population levels a decade later, are seldom subjected to formal cross-impact analysis.

Communicability of Results

Circumstances vary, but in general the communicability of cross-impact analysis is good. The basic concept of interrelating consequences in matrix form is easily grasped. Time-sequencing into scenarios further enhances communications.

Credibility of Results

Credibility of results ranges from high to doubtful, depending on the subject matter. Many scenarios based on cross-impact analysis are intended less to be "credible" than to illustrate the consequences of given events. It seems to be a law of human nature that outcomes that we consider desirable are more credible than undesired outcomes.

Span of Forecasts

Forecasts can be of any duration, although, as in most forecasting methods, credibility tends to decline with length of span.

Resources Needed

The most crucial resource is imaginative people knowledgeable in the field being analyzed. This is a difficult combination to find in many areas of engineering and science. The kind of problem selected for cross-impact analysis usually benefits most from imaginative thinking, whatever the person's level of expertise in the subject matter. Some of the more systematic creativity techniques, such as synectics, argument by analogy, or brainstorming, are sometimes helpful in performing cross-impact analysis.

To complete a cross-impact matrix is difficult and taxing work. Computerized assistance is essential if complex simultaneous interaction must be evaluated or if the consequences of alternative trends and options are to be explored. Requirements of time and money for a complete cross-impact analysis depend wholly on the nature of the problem. Estimates range between $5,000 and $50,000.

An existing cross-impact computer program is available from The Futures Group, Glastonbury, Connecticut. The cost of the program, documentation, and one day of instruction is approximately $2,000. The cost of actually running the program is minimal--$2 to $5 per run.

Procedures

The skills involved in performing cross-impact analyses range from elementary to beyond the skills of anyone. Most planners will need help from subject specialists if any of the events being evaluated are complex (e.g., institutions, attitudes, technology). Since, as remarked earlier, the technique is usually applied to nonobvious relationships, this means that most cross-impact analyses require a team of specialists working under the direction of the planner.

Case Example

Cross-Impact Analysis of Demographic Factors

In the following discussion, a generalized cross-impact procedure is used to evaluate the probable effects of lower population and related factors on the Corps civil work mission. There are six main tasks:

- Identify issues
- Identify events that affect the issues
- Construct cross-impact matrix
- Calculate new probabilities

* Use the matrix to answer questions
* Evaluate results.

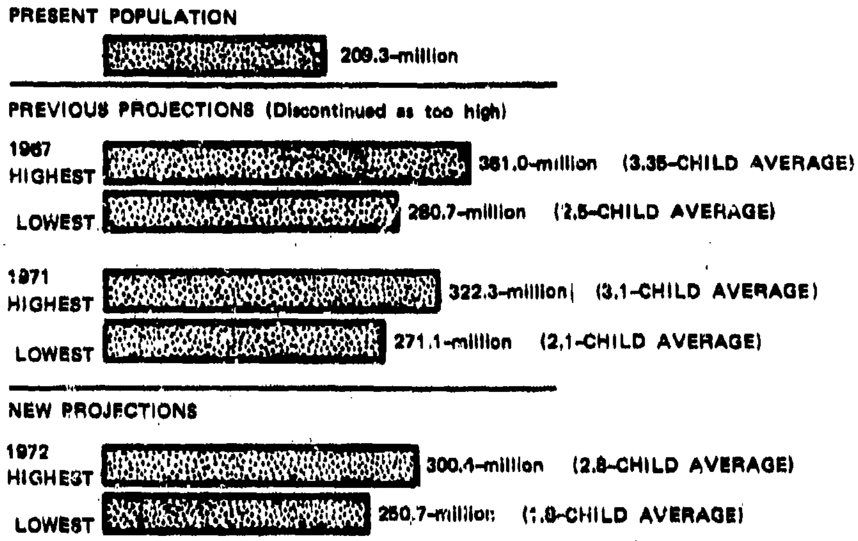
Identify Issues--Flood control, navigation, water supply, beach erosion control, hydropower, recreation, and water quality have been identified as seven major issues in the Corps mission. Work in the areas of recreation, water supply, and water quality seems to be increasing while activity in the area of hydropower has been substantially reduced. Flood control, navigation, and beach erosion projects have remained fairly constant over the past decade.

Identify Events--On December 17, 1972, the Census Bureau issued new population projections for the United States for the year 2000. These were drastically lower than previous projections. The essence of the changes are shown in Figure 21.

The new projections indicate that the total population of the United States may increase by only 20 percent by the year 2000 instead of the 50 percent anticipated by earlier projections. However, even Series F* projections still show a net increase of 42 million people, and the water resource development needs of these people may be different from those for a larger population.

Regardless of which population projection is eventually used for planning, the effect on near-term (1980) water needs is minimal. The projected rate of household formation through the mid-1980s is

*U.S. Department of Commerce, Projections of the Population of the United States, 1970 to 2020, P-25, No. 493, GPO.



SOURCE: Bureau of the Census.

FIGURE 21 CHANGES IN POPULATION PROJECTIONS FOR THE YEAR 2000 (Published in the New York Times, December 18, 1972).

on the order of 1.2 to 1.5 million per year as compared to a 1960s average of 1.0 million per year. The pressure for resource development during this time span is "locked in" by the age distribution of the existing population.

The President's Commission Report* assumes a doubling of GNP regardless of the rate of population growth. This assumption is accepted herein, with reservations about the conclusion. The rate

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*Report of the President's Commission on Population Growth and the American Future.

of growth of GNP should be sensitive to a number of interrelated variables that are in turn keyed into population growth (such as population ⟶ water quality ⟶ investment in pollution control ⟶ GNP) and alternative GNPs may be more important than alternative population levels as far as water needs are concerned.

Other interrelated trends could result in mutually supportive or mutually cancelling effects. Increased per capita income (with more discretionary income) plus shorter work weeks could result in a significant increase in recreation demand that could more than counterbalance decreased demand from a smaller and older total population. These relationships are not clear enough at the present time to draw firm conclusions, but these chains of effects could be critical to Corps programs.

The most important effect may center on the distribution of future populations, not on the size of the population itself. A continued concentration of population in coastal regions and out-migration from the interior may intensify water-related problems in some regions and reduce them in others.

If only lower population projection is considered in relation to Corps missions, the effects on current levels or expectations could be assessed as generally negative, as shown in the tabulation on the following page.

However, many economic and demographic factors associated with population growth are both interrelated and interactive. These include: aging, population, GNP growth rate, per capita income, leisure time, urbanization, and increased household formation.

Mission	Effects: Lower Population Growth Rate
Flood control	Less
Navigation	No effect
Water supply	Less
Beach erosion control	Less
Hydropower	No effect
Recreation	Less
Water quality	Less

Table 15 expands on the foregoing chart and displays an assessment of the relative importance of selected economic and social indicators on many of the Corps missions. Again, the evaluations shown are with respect to current levels or expectations.

Construct Cross-Impact Matrix--A cross-impact matrix can be completed for the most important events assessed in the effects chart in order to provide insights into the interactions of those events upon each other. Thus, for purposes of illustration, the following events have been selected as the most important* and assigned initial probabilities as follows:

Event No.	Event Name	Probability of Occurrence by 1980 (initial probabilities)
1	Lower population growth rate	0.8
2	More leisure	0.9
3	More urbanization	0.7
4	More household formation	0.6

*There is, of course, no ban to using any number of factors except the increased complexity of the procedure.

Table 15

ASSESSMENT OF THE EFFECTS OF POPULATION ISSUES ON CORPS MISSION EVENTS

Mission	Effects of Events						
	Lower Population Growth Rate	Aging Population	Maintain GNP Growth Rate	Increase Per Capita Income	More Leisure	More Urban-ization	Increased Household Formation
Flood control	Less	No effect	No effect	More	No effect	More	More
Navigation	No effect	No effect	No effect	No effect	More	More	No effect
Water supply	Less	No effect	No effect	More	No effect	Much more	More
Beach erosion control	Less	Less	No effect	Much more	Much more	Much more	More
Hydropower	No effect	No effect	No effect	No effect	No effect	No effect	No effect
Recreation	Less	Less	No effect	Much more	Much more	Much more	More
Water quality	Less	No effect	No effect	Much more	More	Much more	More

The assignment of probabilities should engage the most knowledgeable people available. The cross-impact interaction values are obtained by using a panel of experts, or inputs from a Delphi. In an intraoffice situation, a mini-Delphi survey would be useful for quick approximation.

The cross-impact matrix is set up by listing the events as row and column headings of a table. The initial probabilities of occurrence are shown in parentheses beside the events. Participants are then asked to estimate conditional probabilities, assuming each event in turn were to occur. Thus, the numbers in the matrix are referred to as conditional probabilities. The completed cross-impact matrix with estimates of conditional probabilities is illustrated in Table 16.

Calculate New Probabilities--With no frequency information, a nonoccurrence matrix is calculated using standard statistical definitions.* To illustrate the analysis of such a matrix, we can follow Theodore Gordon's computer process step by step.

- From among the events, one is selected at random, say Event 3.
- A random number (from 0 to 1) is generated by the computer and compared with the initial probability

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*$P(R/C') = [P(R) - P(C/R) \cdot P(C)] / [1 - P(C)]$

where R represents a row
C represents a column
P(R/C) represents entries in the matrix
P(C) represents initial probabilities
P(R/C′) probability of R given C does not occur

Table 16

OCCURRENCE MATRIX

If this event were to occur ↓	...then the "new" probability of occurrence of these events would be:			
	Lower Population	More Leisure	More Urban	More Household
1. Lower population (0.8)		0.99	0.65	0.4
2. More Leisure (0.9)	0.85		0.65	0.6
3. More urban (0.7)	0.8	0.9		0.7
4. More household (0.6)	0.8	0.9	0.8	

Values in parentheses ( ) are the initial probabilities.

Values in the matrix are referred to as conditional probabilities.

of Event 3. Say the selected number is 0.6. Since the initial probability of Event 3 is greater than the selected number, the event is recorded as having occurred. (That is, for the first pass the value for Event 3 is recorded as 100 percent.)

- The initial probabilities of the remaining events are adjusted* as indicated by the conditional probabilities in the occurrence matrix. Thus, population stays the same--0.8; leisure stays the same--0.9; and households increase to 0.7. Note, if the event is recorded as not having occurred, the probabilities of the remaining events are adjusted as indicated in the nonoccurrence matrix. (The nonoccurrence matrix, calculated from the occurrence matrix, is not illustrated in this example.)

- A second event is selected at random from these remaining events, say Event 4 (excluding Event 3 since, for this sequence, its occurrence has already been decided).

- The procedure described in Step 2 is repeated. Thus, Event 4 is decided on the basis of its new probability. (Note, the new probability for Event 4 is now 0.7.)

- Now, the probabilities of the remaining events are computed depending upon whether Event 4 "occurred" or "did not occur."

- The occurrence or nonoccurrence of the events are decided in this manner. At the end of the sequence a "happen" or "didn't happen" notation is associated with each event. For example, Events 2, 3, and 4 are recorded as "happened," while Event 1 is recorded as "didn't happen."

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*For a more detailed discussion of the mathematical adjustment see John Stover, "Suggested Improvements to the Delphi/Cross-Impact Technique," _Futures_, Vol. 5, No. 3, pp. 308-313 (June 1973).

- The process is repeated many times, typically 1000, to arrive at a final probability estimate: this represents a new scenario. Final probability estimates are computed for each event based on the number of times each appeared during the process. For example, if Event 1 was recorded as having occurred 500 out of the 1000 times, its final probability estimate in the new scenario would be 0.5.

Use the Matrix to Answer Questions--Following the computer run, the initial and final probabilities are adjusted to coincide and the matrix can then be used to answer questions or test policies in the form of "what if" questions.

For example, what if the federal government were to pursue a policy of forceful subsidization of new house construction, such as the $2,000 tax credit recently adopted? What would the effect be on the other factors being considered?

Evaluate Results--By raising the probability of more household formation to 100 percent (this is to say that the event occurred) the computer would produce results such as the following (this is not a computation and is only intended for illustrative purposes).

		Probability of Occurrence by 1980	
No.	Name	Initial	Household Formation at 100 Percent
1	Lower population growth rate	0.8	0.5
2	More leisure	0.9	0.8
3	More urbanization	0.7	0.9
4	More household formation	0.6	1.0

A similar analysis can be made with respect to each of the other factors.

In order to arrive at an overall assessment of future changes in Corps missions, results from the impact matrix can be compared with the effects of a single population event, as in Table 17.

Table 17

IMPACTS ON CORPS MISSION FROM OCCURRENCE OF LOWER POPULATION RATES

Corps Mission	In Isolation	With Interacting Events
Flood control	Less	More
Navigation	No effect	More
Water supply	Less	Much more
Beach erosion control	Less	Much, much more
Hydropower	No effect	No effect
Recreation	Less	Much, much more
Water quality	Less	Much, much more

The conclusion implied by the above is that a lower population growth rate, when examined in the light of other interacting events, would create a somewhat different set of water resource needs, and generally in the direction of increases in the Corps missions, with particular emphasis on beach erosion control, recreation, and water quality. Additionally, it might be concluded that the Corps mission is more sensitive to population shifts (concentration or dispersion) than to population growth itself.

KSIM

General Description

Abstract

KSIM is a cross-impact simulation technique used to better forecast and assess long-range requirements and impacts of water resource development alternatives. The technique provides a tool to interface broad planning issues with detailed dynamic models so that more effective use can be made of planning resources. Both qualitative and quantitative data can be used--a unique characteristic. KSIM combines a small group workshop procedure with a mathematical forecasting model and a computer program to generate changes over time in a few significant planning variables. The method helps to identify planning needs, develop models, and test the consequences of policy actions. The technique requires expert leadership and access to a computer. A KSIM computer program is available.

Definition

KSIM presents a mathematical means of articulating and visualizing what people sense to be the relationships among a number of interacting variables. As a simulation tool, it combines expert opinions with analytical computing techniques to analyze relationships among broadly defined variables in environmental and socioeconomic systems. The technique enables a team of people, first, to define and structure a set of variables describing a perceived problem and then, using an interactive computer program, to calculate and display the changes in the variables over time. By observing the changes and then making modifications and refinements, the team develops a model of the problem situation. With the model, individuals can test various alternatives and review and improve their understanding of the problem. Like all simulations, KSIM seeks to establish "if-then" relationships; however, KSIM has the distinctive feature of accommodating subjective or intuitive concepts as well as quantitative data.

Assumptions

KSIM shares with other model and simulation techniques the general assumptions that a satisfactory model can indeed be devised and that the relationships among parts can be defined, at least qualitatively. Specific to the KSIM procedure are the assumptions that realistic bounds on all system variables can be set and that S-shaped curves are adequate to describe change patterns in human affairs.

History

KSIM was developed in the early 1970s by Dr. Julius Kane on the premise that "it is the 'soft data'--value judgments, opinions, cherished notions--that control the dynamics of the politics machine. If computers are to be effective instruments of policy, then they must have open channels that can accept subjective data and give it its proper role." Although the technique is quite new, there have been a number of applications. These include:

- Water resource planning--Corps of Engineers.
- Impact assessment workshops--Institute for Water Resources.
- New ventures or products--Pilkington Brothers Ltd., England.
- Environmental planning--Departments of Environment and Industrial Trade, Canada.
- Educational tool for systems analysis--University of British Columbia, Portland State University.

Main Uses

KSIM is useful for problem formulation, "needs" identification, and communication. It allows planners to understand system structure, relate quantitative and qualitative factors, and directly communicate their perceived outcome of proposed planning interventions. Corps planners can use KSIM to study the implications of changes that result from the interaction of system variables or from implementation of alternative policies of water resource planning. It can also be an effective procedure for incorporating community or expert opinion into water resource planning.

Limits and Cautions

The simulation does not tell planners what alternative solution to choose. Rather, it is an information and display device by which major issues, needs, and concerns emerge. The procedure is designed to handle broad variables and to be applicable only in the early stages of Corps planning. Special caution must be exercised in translating human intuition into mathematical terms. In using KSIM, as well as other techniques based on feedback, it is necessary to keep alert to the possibility of a variable evolving beyond some reasonable limit.

Other Techniques

KSIM is a blend of many techniques. Therefore, depending on the situation, planners may usefully use brainstorming, authority forecasting, panels, or Delphi for collecting expert opinions; cross-impact analysis or input-output analysis for assessing interactions; dynamic modeling for simulation; and alternative futures or scenarios for assessing the outcome of projects under various conditions.

Product or Result

Ideally, the initial product of a KSIM simulation is a working model of the problem. The model is used to test planning options by exploring how a range of likely futures may affect a given plan or by examining how various changes, such as in public preferences, could alter outcomes of plans. The output appears either as columns of numerical forecasts or as graphics illustrating the changes of significant variables over time. However, in KSIM sessions it is often the process (exchange of views, surfacing of issues, identification of concerns, and so on) that is more important than the product.

Level of Detail

KSIM deals with aggregate variables (up to 12 in number) and structural relationships and does not give precise numerical answers. Output values for all variables range between zero and one.

Level of Confidence

The model reflects the experience and judgments of the team members. While the results may be limited by the availability of "hard data," the confidence in results is usually governed by the level of confidence placed in the participants.

Communicability of Results

Results from a KSIM exercise are generally straightforward and easy to communicate. The cross-impact matrix clearly illustrates the relationships among variables. Outputs for various alternatives can be readily displayed and compared.

Credibility of Results

When presented as the team's perception of the existing situation and of changes due to planning, the results are generally accepted. However, the KSIM technique is fairly new and has not undergone extensive testing. Thus, its credibility as a forecasting technique is yet to be established.

Span of Forecasts

The procedure is designed to accommodate both short- and long-term relationships. However, since the concepts usually involve broad first-state planning objectives, long-term (30 to 50 years) forecasts are the most common.

Resources Needed

Required resources include a leader, participants, and access to a computer. An experienced coordinator is required to lead a formal KSIM workshop. Hence, while a workshop providing solutions to a given problem can be completed in less than a week, there is a requirement either to hire a leader or learn the procedure. It is estimated that learning the subtleties of KSIM could take anywhere from a few days to a month or more, depending upon the background of the potential leader. Participants should be experts in their designated fields, but need no experience in mathematics, modeling, or systems analysis. The KSIM computer program is available on-line or batch via IWR or the Waterways Experiment Station at Vicksburg. A workshop may cost several thousand dollars or more, although each computer run for a specific case costs only a dollar or two.

Procedures

Most planners will need guidance on procedures in conducting their first KSIM forecasts. Depending on the topic, specialists on the subject matter will also be required. Even so, KSIM is essentially a fairly simple, straightforward method that can be mastered with a little experience.

Case Example

KSIM Simulation of Impacts of Deep Water Ports

The KSIM cross-impact simulation is used below to assess some of the broad, long-term impacts of U.S. deep water ports (DWP). Steps for a small group KSIM workshop include:

- Preliminaries--select the group and the setting
- Formulate the problem
- Identify the significant variables
- Develop a cross-impact matrix
- Refine the model
- Examine alternatives
- Draw conclusions.

Preliminaries--KSIM workshops are best conducted at locations free from distractions and interruptions. There should be a computer terminal available and access to a telephone line (for the computer).

Next, a team of people knowledgeable about the subject but with diverse backgrounds and interests should be selected. The ideal team size varies from five to eight, including experts and team coordinators.

Formulate the Problem--The workshop problem was to assess the impacts of DWP for oil imports.

During the problem formulation session, the team identified numerous local, regional, national, and possible global impacts from DWP. However, to limit the scope of the problem for the workshop exercise, the team chose to consider only the national implications of a U.S. DWP policy. The basic assumptions were:

- There is an energy shortage
- DWP are needed to overcome the shortage
- Imports are available via ocean shipping.

The alternatives to be tested during the workshop included:

- What if crude oil imports were cut off?
- What if the United States implemented a policy to develop DWP?
- What if DWP are developed and then foreign imports are cut off?
- What if DWP were developed with a ceiling on energy use?

Identify the Significant Variables--The KSIM panel structured a national DWP system using five aggregate variables: energy use, domestic energy supply, domestic investment, reliance on traditional sources, and public confidence (see Figure 22).

All variables in the system were defined, labeled, and scaled to range from a minimum value of zero to a maximum value of one. Initial values were estimated within the zero-to-one range.

Energy Use refers to the nation's energy demands. Implicit in the first assumption is the policy to meet the projected 4 percent per annum growth in energy demand. The maximum was

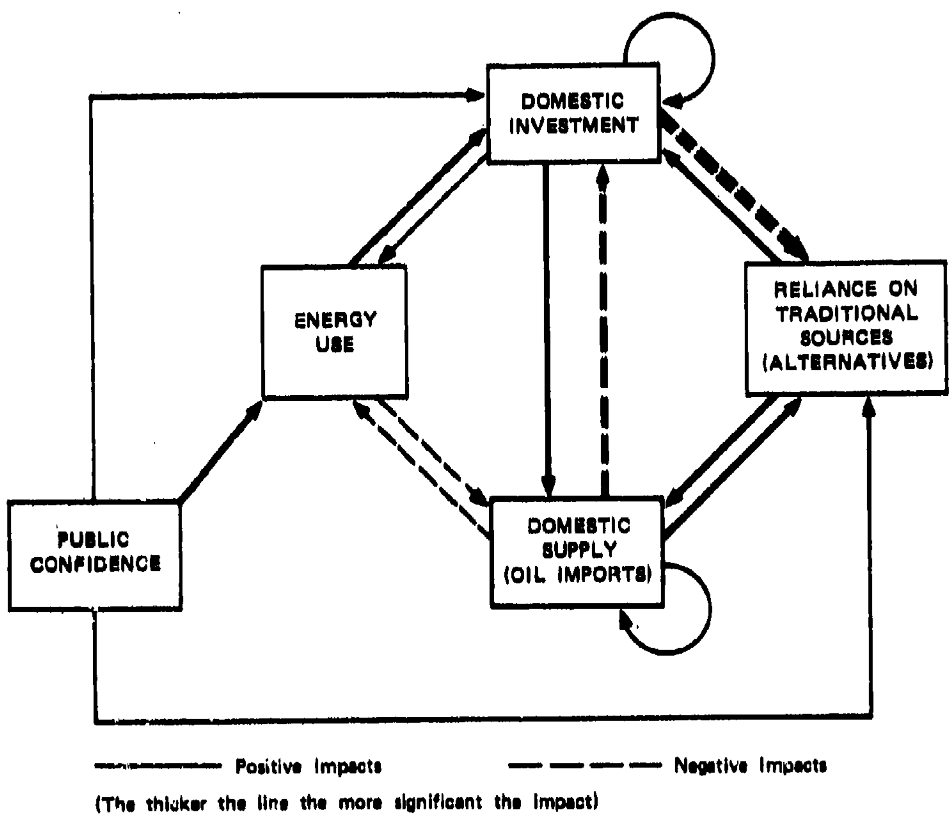


FIGURE 22 U.S. DWP SYSTEM

estimated at four times present use. Zero energy used was set as the minimum. The initial value for energy use was estimated at 25 percent of maximum possible use.

Domestic Energy Supply is a direct measure of the U.S. energy import situation. A value of one means that the United States is totally self-sufficient. Zero indicates that all U.S. energy is imported. It was hypothesized that people would feel threatened by increasing dependence on foreign energy sources. Considerations include a monetary crisis and possible foreign conflicts. Currently, the United States imports only 10 percent of its energy; thus the initial value for domestic energy supply was set at 0.9.

Domestic Investment was used to indicate the national incentive to invest in new energy reserves and sources. This includes both economic and social incentives for new exploration, and research and development of alternative sources, such as solar, geothermal, breeder reactors, and fusion power. A maximum domestic investment was perceived to be 10 percent of GNP, with a minimum being no investment. The present domestic investment was assessed at 0.05.

Reliance on Traditional Sources or Energy Alternatives is an index of U.S. flexibility with respect to energy. The energy alternatives refer to the physical parameters of time, technology, and money, as well as the social alternatives, such as conservation, attitude, and institutional organizations. Figure 23 illustrates the transition from traditional energy sources to new technologies

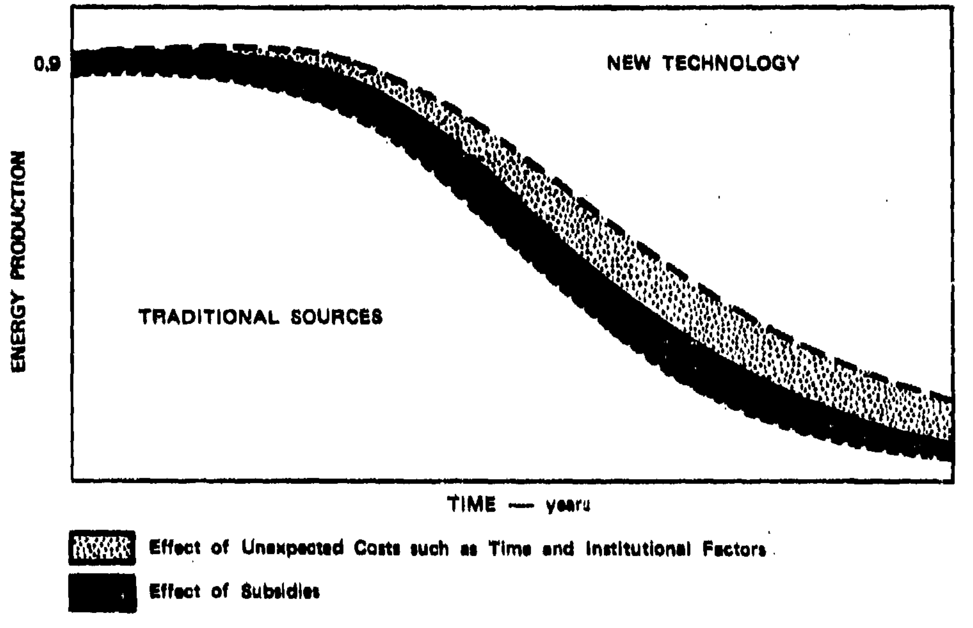


FIGURE 23 U.S. DEPENDENCE ON ENERGY SOURCES

over time. At present, we depend on the traditional sources of coal and oil for 90 percent of our energy.

Public Confidence was used to register both short-term fluctuations in public satisfaction and the long-term trust of the American people in their government. The long-term trend was perceived as fairly constant with a slight decline. The upper limit of one referred to complete trust, while the zero value indicated "not satisfied." The long-term lack of satisfaction is expressed not through revolution but rather through apathy.

Outside World. An exogenous variable labeled "outside world" was also used to indicate the interactions among the national system and subsequent local, regional, and global systems.

Develop a Cross-Impact Matrix--The cross-impact matrix shown in Table 18 provides the structure for the system. To complete the matrix, the team determined:

- If there was a relationship between two variables. If the answer was no, they entered zero in the matrix. If the answer was yes, they proceeded to the next question.
- If the relationship was positive or negative.
- The strength of the relationship. In this example a range of +3 to -3 was used.

Table 18

DWP CROSS-IMPACT MATRIX

What is the relationship between this variable	... and these variables?					
	EU (0.25)	DES (0.9)	DI (0.05)	EA (0.9)	PC (0.8)	Outside World
Energy use	A	-1.0	1.4	B	2.2	
Domestic energy supply	-1.2	1.4	2.0	1.6	0	
Domestic investment	2.0	-1.8	1.0	2.0	1.0	
Energy alternatives	C	1.8	-2.8	0	1.0	
Public confidence	0.4	0	0.3	0	0	

Entries on the table represent the impact of the column variable on the raw variable. Numbers in parentheses indicate initial values. The average is from five people. Letters indicate conditional relationships as perceived by team members:

A: The impact is positive until EU reach 50 percent of maximum, then the impact is negative.

B: After 1985 there is a positive impact.

C: If DES drops below 75 percent then EU has a positive impact on EA.

Refine the Model--Refinements can be made in the model by adding or deleting variables, redefining the limits or initial values of variables, or modifying the cross-impact values.

To tie the cross-impact values either to reality (items for which data are available) or to estimated data, it is necessary to relate all impact values to rates of change. The values in the cross-impact matrix are scaled by multiplying the values by constant factors, $c\alpha$ and $c\beta$. To determine $c\alpha$, one must decide how much influence Variable A can have on Variable B in one short interval for a maximum positive value, say +3. Suppose this change is 3 percent. Then, in one short interval (say, 0.1 of the forecast period) the scaling factor $c\alpha$ is calculated as follows:

$$c\alpha = \log(1+r)/-\alpha\beta\Delta t \log A$$

$$c\alpha = \log(1.03)/-3 \times 0.5 \times 0.1 \times \log(0.5)$$

$$c\alpha = 0.28$$

where

$c\alpha$ = scaling factor, unknown

r = growth rate, 3 percent

Δt = time interval, 0.1

α = cross-impact value, +3

β = value of the variable, 0.5

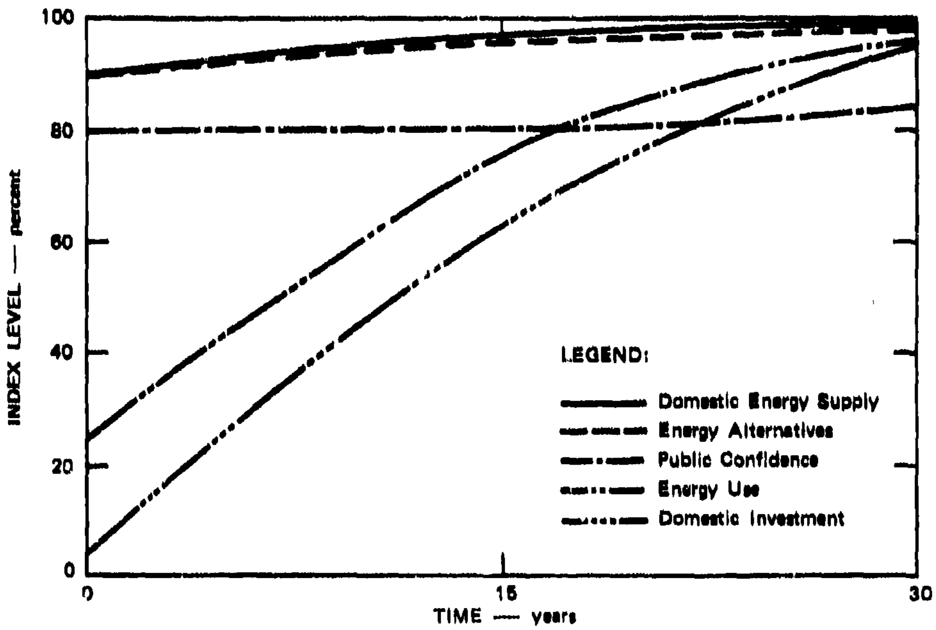
A = value of another variable, 0.5

To determine $c\beta$, a similar process is used, except here Δt cancels out. However, as a general approximation, $c\beta$ can be estimated at 10 times $c\alpha$.

Examine Alternatives--After the variables are defined and agreed upon and the cross-impact matrix scaled, the future states of the system are simulated. The system that emerged as a result of the team's cross-impact structure is illustrated in Figure 24. This is referred to as the base case. Figure 25 illustrates one of the numerous alternatives tested with the DWP model.

Draw Conclusions--As indicated in Figures 17 and 18, KSIM runs reflecting different assumptions point to various specific implications for the variables plotted. In drawing conclusions from such plots, it is well to remember that all KSIM results reflect the biases of the forecasters, the shortcomings of the model, and inadequacies of data. It is for these reasons that the process is often fully as valuable as the specific conclusions of the work.

CONSIDER: Initial Projected Variable Interactions of the National Deep Water Port System

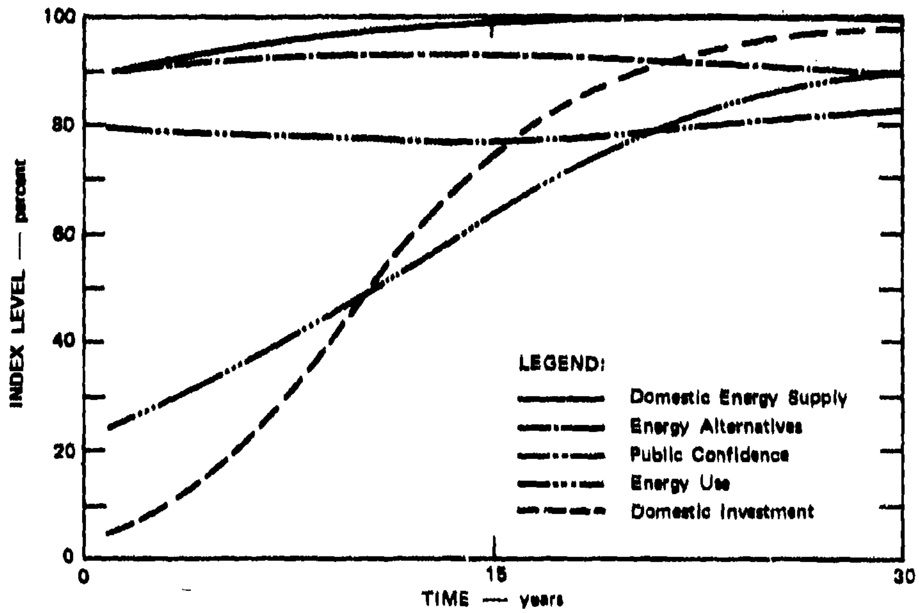


IMPLICATIONS:

Domestic investment increases steadily to near maximum.
Energy use increases steadily to near maximum.
Public confidence is stable.
Domestic energy supply increases to maximum.
Energy alternatives increase to maximum.

FIGURE 24 BASE CASE

CONSIDER: Crude Oil Imports not Available.
Impact of Outside World on Domestic Investment is Positive.



IMPLICATIONS:

Domestic investment lags then increases rapidly and reaches upper limit. Over 70 percent of increase occurs in first half.

Energy use increases at slower rate.

Public confidence dips in first half and then recovers.

Domestic energy supplies rise to maximum in first half.

Energy alternatives rise in first half and then decline.

FIGURE 25 CASE WITH NO IMPORTS

INPUT-OUTPUT ANALYSIS

General Description

Abstract

Input-output (I-O) analysis is a means of interrelating industry inputs and outputs in a single model, showing the consequences to all other sectors of a specified change in one. Different models deal with the nation, with regions, with specific industries, and so on. I-O analyses are of great value in quantifying changes in a region's or subregion's commodity flows and likely industrialization patterns resulting from specific projects--such as improved navigational facilities or a new recreational site. Principal problems to its use include lack of detail in coverage in I-O matrices, out-of-date data, and the high cost of developing speciality I-O tables.

Definition

Input-output analysis is based upon a descriptive model of the economy or a portion of it. I-O refers to the flow of goods and services among industries during the process of manufacture and then to final users (or GNP). I-O tables are constructed to show this flow either for all industries and final users or for a selected group of industries and final users. An I-O table may show the flow of goods and services with a metropolitan area, state, a nonpolitical region, such as a river basin, a country, or even a group of countries. It customarily includes all the transactions or flows of goods and services that occur, or are expected to occur, in a particular year. I-O tables are usually produced in each of three different forms: one covering dollar transactions, one, direct requirements, and one, total requirements.

I-O analysis is the use of I-O tables and projections to assist in tracing, predicting, or evaluating the effect on a particular industry or region of changes in the demand for goods and services by final users and by other industries. Many I-O tables have been computerized to make it easier to insert desired changes.

Assumptions

The central concept in I-O is "the idea that there is a fundamental relationship between the volume of the output of an industry and the size of the inputs going into it" (Leontief, 1966). Its usefulness rests on the assumption of a stable pattern of those relationships. The basic assumptions are as follows:

- Each commodity is produced by a single sector--here the main problem is one of aggregation.
- Inputs to each sector are a direct linear function of that sector's output. Within the static model, this means that technology does not change over time--an assumption that is hard to live with in the 1970s.
- There are no externalities involved in the production process, suggrsting a state of self-sustaining growth.

History

Interindustry I-O analysis received its present-day impetus from Wassily W. Leontief, Nobel Prize winner of Harvard University, who published the first national I-O table in 1936. The basic concept of a table of the economy was developed nearly two centuries ago by François Quesnay. Then in the early 1900s, Leon Walras developed the mathematical equations for the economic principles. During the past 15 years, many national I-O tables have been developed for studying and projecting economic growth patterns and the potential impact of major policy moves. Over 60 countries now have a table of some kind, and a single integrated table has been published for the European Common Market. In addition, a number of regional I-O tables have been developed for individual states, multistate regions, major watersheds, and metropolitan areas. The most recent national I-O table for the United States was published by the Department of Commerc in 1974.

Water-related multiregional I-O tables have been developed at the University of California at Berkeley (Davis, 1968). Computer programs, documentation, and certain data are available as part of the U.S. Army Corps of Engineers SIRAP program housed at the Lawrence Berkeley Laboratory. A multiregional I-O model developed at Harvard for EDA is available on BEA computers and SIRAP. There are 51 state tables (including the District of Columbia). IWR has developed procedures for converting state tables into a total of four regions. The smallest size is one OBERS region.

Main Uses

The Corps of Engineers could use I-O for studies designed to reveal the interrelationships between various sectors of the economy and the marginal value of water within such a structure in stimulating or inhibiting economic growth. For this purpose the technique has unique capabilities. With the development of water-use I-O, matrices have been used more as a means for structuring and representing information than for generating new information.

Through the use of coefficients, I-O models can forecast not only those sectors of the economy directly responsible for the consumption of water, but also those industries that exert considerable indirect demands for water through interrelationships with other sectors in the economy. Combined with optimizing techniques such as linear programming, a time path of "shadow prices" of water can be identified for productive sectors of the economy dependent upon water availability.

Limits and Cautions

Two basic cautions must be observed in using I-O analyses:

First, data for I-O tables are usually fairly old. For example, the national industry table issued late in 1969 used information collected in 1963. The 1974 update uses 1967 data. On the average, tables reflect industry flows and technologies of about eight years earlier. This is a serious deficiency, since the economy and technology are far from static. To remedy the situation, some analysts have attempted to update old data by estimating new technical coefficients linking sectors of the economy.

Second, data often are not fine enough for all the analyses one might wish to make. The 1969 national table covers 367 industrial sectors. Enormous as this is, there is often need for specific data on regions and localities and for nonindustry categories. Resort may be had to specialty tables developed by private organizations. These sometimes are more directly pertinent, but unfortunately they often use data and coefficients of questionable validity. Moreover, it is extremely difficult to update coefficients for fast-changing domains of the economy.

Other Techniques

I-O is clearly superior to other cross-impact and relevance techniques for measuring many kinds of interindustry relationships. In terms of accounting systems, the alternatives are national income accounts, flow of funds, balance of payments, and wealth and balance sheets. However, no other method attempts to compete with I-O in furnishing a comprehensive description of the interindustry relationships within a region, or a detailed analysis of the impact of change in the national economy.

Product or Result

An I-O table consists of a matrix with identical industry (or other) categories on each side. In each cell appears a number (a coefficient) that indicates the relationship of the industry sector identified on one axis of the matrix to the sector on the other axis. In total, the matrix defines interrelationships among all sectors treated in the table. Different tables reflect dollar flows, direct interindustry requirements, and total requirements. Forecasts from a water content matrix can illustrate water requirements and water withdrawal requirements. The results can also provide an indicator of water use by industry.

Level of Detail

Results are extremely detailed.

Level of Confidence

An I-O table projection can be no better than the individual forecasts of final demand (GNP) and the industry input coefficients that are combined to make it up. Confidence in these matters depends largely on one's expectations and grasp of what is and is not included. Use of automated data reduces confidence. Nevertheless, there is widespread agreement that I-O relationships warrant more confidence than those derived in other ways. Regional I-O analysis is extremely sensitive to changing trade patterns.

Communicability of Results

In a technical sense, communicability is very low. Results are usually presented in technical, mathematical form and reflect great numbers of hidden assumptions. For example, roots and bases of the forecasts used in developing tables are rarely understood in detail.

In a general sense, the concept of levels of interdependence among industries is easy to grasp.

Credibility of Results

Credibility is good in the sense that I-O data often are the best available anywhere. It is not good in the sense that few practitioners believe it is possible to develop truly accurate and up-to-date tables.

Span of Forecasts

I-O is usually used for short- to medium-range forecasts. Although it could be used for long-range forecasting, it is not uniquely adapted for that purpose.

Resources Needed

Given a suitable I-O table, much analytical work can be done with it by personnel of minimum training without an excessive expenditure of time.

The situation is very different if a more specialized table must be devised or if an old table must be updated. Cost and time requirements exceed the capabilities of all but large organizations. Generally, it is best to pay a qualified consulting firm to develop the information if it is determined that the cost of a new table is warranted.

Access to a high-speed computer is a must for I-O analysis.

Procedures

As indicated above, it is one thing to use I-O tables and an altogether different thing to construct a table. The first is relatively easy; the second is a task for a large group of specialists.

In view of this, we make no attempt in this Handbook to instruct planners in the building of I-O tables. Instead, we quote several excellent pages on how one reads such tables.

Once one understands the tables, they can be used by planners in two procedurally different ways.

First, as shown in Figure 16 at the start of Section IV, I-O data can be used to feed into comprehensive computerized simulations such as KSIM or dynamic models.

Second, I-O can be used to forecast the implications of specified changes by:

- Assuming an event affecting a given sector, such as adding agricultural output by increasing water supplies.
- Estimating impacts on the sector's inputs and outputs.
- Recalculating coefficients among sectors as a result of the introduced event.
- Tabulating the results of the change in one sector on all interconnected sectors together with the feedback implication for the original sector.

Case Example

Description of a Regional Interindustry Economic Transactions Model (Quoted from Davis and Lofting, 1973)

"1. Partial vs. General Equilibrium Analysis

"The economic activities within a region may at times be grouped into a number of industries or sectors in order to facilitate economic analysis. These sectors will not generally be independent of each other as there will usually be flows of goods and services between the sectors. Judgements as to the nature and extent of these flows will govern the choice between a partial or general equilibrium approach to the analysis of many regional economic issues.

"Suppose the analyst is interested in the effects upon a particular sector of a change in the market demand for its production. It may be that the resulting change in the sector's production will have repercussions on other sectors in the regional

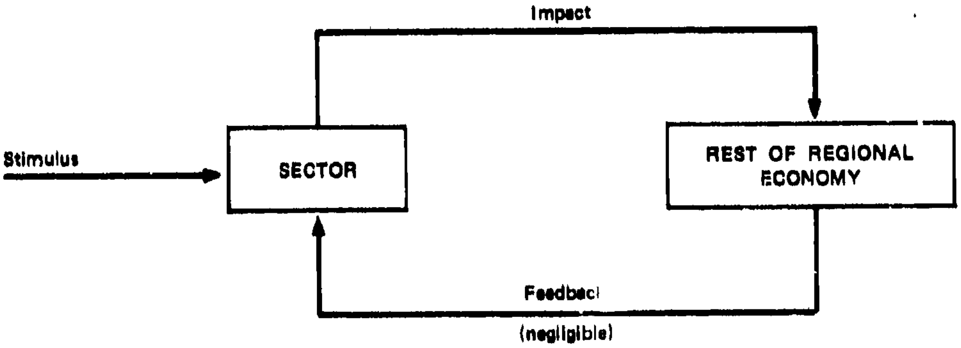


FIGURE 26 CONDITIONS FOR PARTIAL EQUILIBRIUM ANALYSIS

economy. Moreover, these repercussions may in turn affect, or feed back upon, the sector in question. The basic assumption of partial equilibrium analysis is that such feedback to the sector under study is sufficiently small to be ignored.

"On the other hand general equilibrium analysis is appropriate if feedback upon the sector is significant or if the analyst is interested in the effects (impact) of the initial stimulus upon other sectors of the regional economy. Under general equilibrium analysis, relationships between sectors of the economy are explicitly taken into account and the entirety of the economy is brought under examination.

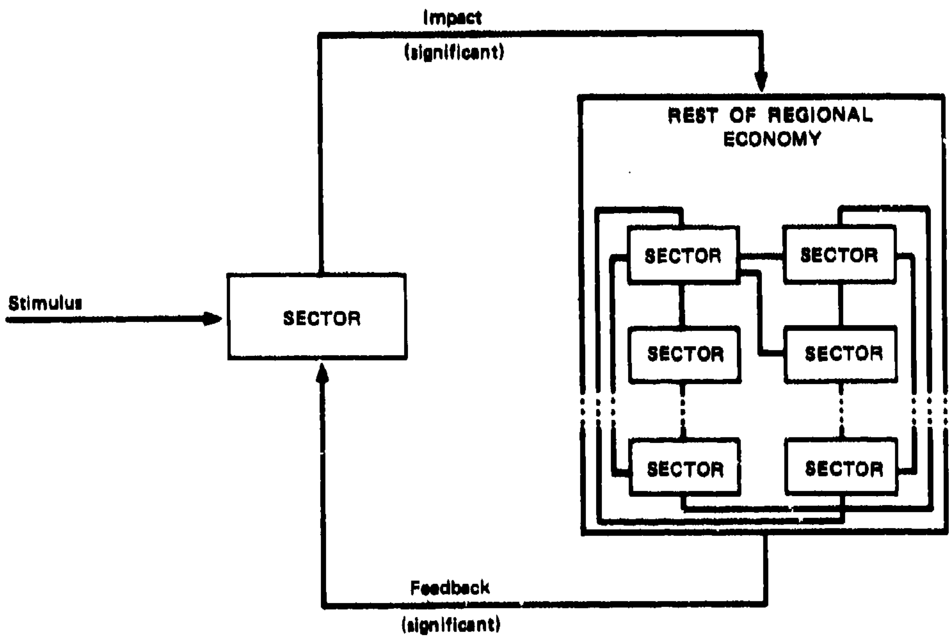


FIGURE 27 CONDITIONS FOR GENERAL EQUILIBRIUM ANALYSIS

"In a pure equilibrium model each variable in the model depends only upon other variables within the model and hence all variables are endogenous. That is, values for all variables are yielded by the model and none must be determined exogenously.

"In the 1930s Wassily Leontief formulated a mathematical description of the U.S. economy constructed from data regarding economic transactions between industries. The effort stands as the first operational economic model to embody the essence of general equilibrium. The model is not strictly a pure equilibrium model since, as we shall see, some of the key variables of the model are exogenous, i.e., values for these variables must be determined outside the model itself and then 'plugged in.'

"Leontief's model came to be labelled 'input-output' as it records each transaction between firms in double entry fashion as both a sale of output and a purchase of input. The model represents a general equilibrium approach to the study of an economy and focuses upon the interdependencies between the various economic sectors. Although initially applied on a national level, the model has been used in a proliferation of regional applications in recent years.

"2. <u>The Regional Input-Output Model</u>

"The basic I-O model may be explained in terms of its three associated tables:

a. Table of Interindustry Transactions

b. Table of Direct Requirements

c. Table of Direct Plus Indirect Requirements "a. Table of Interindustry Transactions

"As a first step in the construction of the Transactions Table the regional economy is segmented into a number of sectors (or industries). Just what sectors the analyst chooses to represent the economy depends upon 1) the nature of the regional economy with which he is working, 2) the nature of the problem in which he is interested, and 3) the resources at his disposal. The number of sectors of the typical regional I-O model will be in the neighborhood of 30. Each of these sectors is generally defined in terms of the Standard Industrial Classification (SIC) codes.* Every type of economic activity may be represented by an SIC code number at the 2-digit, 3-digit or 4-digit level. For example, a fertilizer manufacturer would be classified at the 4-digit level as belonging to the category: 2871 Fertilizers. If we were to aggregate our SIC classification to the 3-digit level the firm would be classified under the heading of 287 Agricultural Chemicals. If we were to collapse our categories to the 2-digit level our firm would fall into the 28 Chemicals and Allied Products classification. There are currently 79 two-digit classifications, which comprise 10 divisions. For example, SIC 28 is contained within Division D-Manufacturing.

"However the factors are defined, it is essential that taken together they encompass the entirety of economic activity within the region. For illustrative purposes, the following

*Technical committee on Industrial Classification, Office of Statistical Standards, Standard Industrial Classification Manual, Washington, D.C., 1957.

interindustry Transactions Table contains only 3 sectors or industries.

Table [19]

Transactions Table ($1000)

		Purchasers			Final Demand	Gross Output
		Agri-culture	Manufac-turing	Services		
Sellers	Agriculture	10	5	5	50	70
	Manufacturing	20	30	25	25	100
	Services	5	10	10	55	80
Imports		5	15	5		
Value added		30	40	35		
Gross outlay		70	100	80		

"Since each sector both buys from and sells to other sectors within the economy for further processing, each of the three sectors is listed both at the left of the table as a seller and at the top of the table as a purchaser. The 3 × 3 matrix formed by these sectors is referred to as the 'processing' matrix.

"The final demand sectors represent all sales that are made not for further processing within the region but for final consumption by Households, Government, Investment, and Exports. If a farmer sells milk to a restaurant, the transaction is from Agriculture to Services; if the farmer sells milk to a household the transaction is from Agriculture to Final Demand (Households). If a steel mill sells to a metal fabricating plant within the region, it is a transaction between Manufacturing and Manufacturing; if the mill sells to a metal fabricating plant outside the region, it is a transaction from Manufacturing to Final Demand (Export). Thus each sector's sales are recorded as satisfying either intermediate (processing) or final demand. Gross Output (total sales) of each sector is the sum of intermediate and final sales. Reading along any of the first three rows, we can see how each sector distributed its output over the period. Manufacturing, for example, sold \$20,000 of its \$100,000 total output to Agriculture, \$30,000 to Manufacturing, \$25,000 to Services, and the remaining \$25,000 to Final Demand.

"Reading down any of the first three columns we may see how the particular sector purchased input. For example, Manufacturing purchased \$5,000 from Agriculture, \$30,000 from Manufacturing, \$10,000 from Services, \$15,000 from Imports (goods and services produced outside the region), and \$40,000 from the Value Added sector (roughly wages and salaries, rents, interest, depreciation, dividends, and profit). Gross Outlay (total purchases) must equal Gross Output (total sales) as profits are considered to be the remuneration to management and thus serve as the balancing item. That is, total sales revenue is equal to to total cost plus profit. This point is emphasized below by the diagram representing dollar flows into and out of a sector.

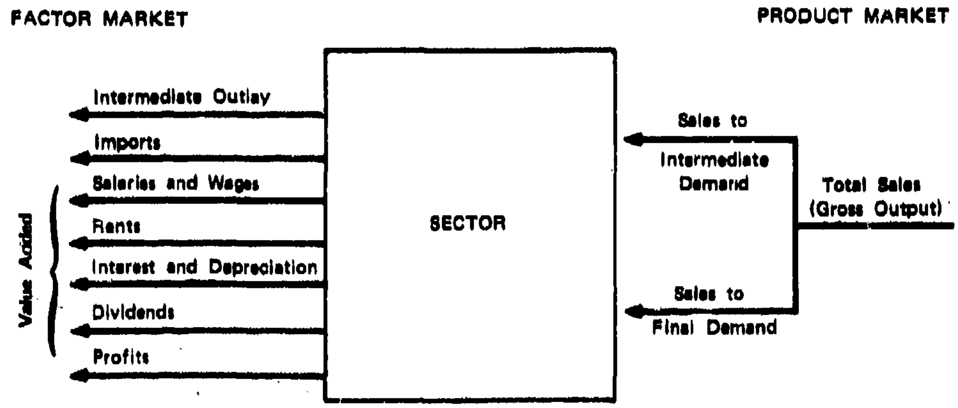


FIGURE 28 SECTORAL MONETARY FLOWS

"The dollar flows are normally those that have been recorded over a period of one year and data pertaining to the flows are gathered by personal and/or mail interviews with each of the firms or a sampling of the firms within each of the sectors.

"b. <u>Table of Direct Requirements</u>

"The Table of Direct Requirements or coefficients is formed by dividing the entries in each column of the processing matrix by their respective column total (Gross Outlay). The Direct Coefficients Table of our illustrative I-O model is Table [20].

"Table [20] reveals that for the average dollar spent by, say, Agriculture during the period, 14¢ were spent on Agricultural inputs, 29¢ on inputs from Manufacturing, and 7¢ on Services. Under the assumption that these coefficients remain fixed, we can forecast the effect upon the regional economy resulting from an increase in Final Demand.

Table [20]

TABLE OF DIRECT REQUIREMENTS PER DOLLAR OF GROSS OUTLAY

	Agriculture	Manufacturing	Services
Agriculture	.14	.05	.06
Manufacturing	.29	.30	.31
Services	.07	.10	.12

"To illustrate, let us assume that the export demand for the output of our regional manufacturing sector increases by $10,000. The manufacturing sector will increase its output by $10,000 to meet this rise in final demand and to do so will have to make the following purchases:

Manufacturing: $10,000	
Agriculture	$10,000 × .05 = $ 500
Manufacturing	$10,000 × .30 = $3,000
Services	$10,000 × .10 = $1,000

"However, in order to produce this supporting output, each sector will require the following inputs:

	Agriculture: $500	Manufacturing: $3,000	Services: $1,000	Total
Agriculture	500×.14 = $ 70	3000×.05 = $150	1000×.06 = $ 60	$ 280
Manufacturing	500×.29 = $145	3000×.30 = $900	1000×.31 = $310	$1,355
Services	500×.07 = $ 35	3000×.10 = $300	1000×.12 = $120	$ 455

These requirements will set off a third round of spending:

	Agriculture: $280	Manufacturing: $1355	Services: $455	Total
Agriculture	280 ×.14 = $39.20	1355 ×.05 = $ 67.75	455 ×.06 = $ 27.30	$124.25
Manufacturing	280 ×.29 = $81.20	1355 ×.30 = $406.50	455 ×.31 = $141.05	$628.75
Services	280 ×.07 = $19.60	1355 ×.10 = $135.50	455 ×.12 = $ 54.60	$209.70

"These rounds of spending will continue with each round becoming weaker in its effects. The accumulated increases in total sales of each sector resulting from the stimulus to the Manufacturing sector of $10,000 in export demand can be computed from the increase in sales of each round.

"While such series of calculations are helpful in understanding the effects that reverberate throughout the regional economy from the initial stimulus, fortunately they are not necessary to determine the ultimate effects. The final changes in total sales (Gross Output) of each sector can be read directly from the third table of the I-O model, the table of direct plus indirect requirements.

"c. <u>Table of Total (Direct Plus Indirect) Requirements</u>

"Generally, with the aid of a computer, our third table may be constructed through inversion of a matrix, associated, as we shall see in the following section, with our second table. For our illustrative model the table is Table [21].

Table [21]

TABLE OF DIRECT PLUS INDIRECT REQUIREMENTS PER DOLLAR OF DELIVERY TO FINAL DEMANDS*

	Agriculture	Manufacturing	Services
Agriculture	1.2117	0.5677	0.1637
Manufacturing	0.1042	1.5542	0.1861
Services	0.1237	0.5956	1.2210

*Transposed

"Table [21] tells us that if there is a $1 increase in the final demand for Agriculture, the total output of Agriculture will, after all the interdependent transactions have worked themselves out, increase by $1.21. Manufacturing and Services in this case will rise $0.57 and $0.16 respectively. We can now easily read from the table the effects of a $10,000 increase in exports of Manufacturing. Total sales of Agriculture will rise $1,000 ($10,000 × 0.10), Manufacturing sales will increase $15,500 ($10,000 × 1.55) and the output of the Services sector will expand by $1,900 ($10,000 × 0.19)."

POLICY CAPTURE

General Description

Abstract

"Policy capture" involves building a model that, given the same information the individual has, will accurately reproduce his judgments and hence his "policies." The goal is not simply to predict or reproduce judgments accurately; rather policy capture seeks to generate descriptions of the judgmental behavior that are helpful in identifying characteristic differences between individuals. It is felt that the judgmental process can be described mathematically with a reasonable amount of success. The technique has greatest Corps application in the areas of public participation and the evaluation of the trade-offs among various goals and alternatives.

Definition

In general terms, capturing a person's judgment policy means constructing a mathematical description of that policy that can be used both to understand present judgments and to predict future judgments. The technique utilizes multiple regression analysis to "capture" the relative weights a person gives to the accomplishment of various objectives. Thus, the method yields mathematically calculated measures to reveal preferences. In water resource planning, policy capture can be used to show the weights various planners, decision makers, and publics use in gauging such objectives as environmental quality, national efficiency, and regional development. In the procedure, people are asked to rate alternative projects that specify different budget allocations for these objectives (Johnson, 1973).

Assumptions

Differences in judgment are considered to be a major source of conflict and misunderstanding. This approach takes the viewpoint that the best, and perhaps the only way to obtain an accurate description of judgment policy is through an empirical analysis of actual judgments. The assumption is that mathematical analyses of judgments can exhibit and clarify the differing policies that are the causes of differing judgments. Moreover, the level of analysis is considered worth the effort, on the basis that conflict often is the result of honest differences in judgment policy, rather than competing self-interests, and that illumination of this point increases understanding and promotes conditions favorable to conflict reduction and management, if not conflict resolution (Stewart and Gelberd, 1973).

History

The policy capture technique was developed by Dr. Kenneth Hammond in the early 1970s at the Institute of Behavioral Science, University of Colorado, Boulder, Colorado (Hammond, 1974). It is based on classic concepts of judgment theory by Tolman and Brunswik dating back forty years.

Policy capture has been applied in the areas of the public sector for policy analysis, government planning, citizen participation, community goals, and land use allocation. In the private sector, applications include award of loans, forecasting interest rates, business promotions, and conflict resolution in labor management.

Main Uses

The procedures are flexible enough to be useful for a wide variety of problems. The analysis may be carried out in any desired degree of depth, from a limited study (i.e., allocation funds among five categories) to an extensive study involving a variety of procedures and objectives. The major contributions are that it externalizes the decision process, gives an objective basis for communication among decision makers, and provides a model for repetitive decisions. Policy capture can be an effective means of including both individual citizens and representatives from stakeholder groups in the planning process. It is an excellent public participation tool because it allows citizens to make judgments about combinations of goals and to evaluate trade-offs.

Limits and Cautions

Three general cautions or pitfalls are associated with the policy capture procedure. First, it is difficult to select appropriate variables with which to work; moreover, the form in which they are presented is critical to the methodology. Second, due to time requirements, it is often difficult to involve high-level decision makers. The people who carry out the analysis must be interested (take it seriously), repeat the process several times, and be properly guided. Finally, the use of linear regression has drawbacks for conducting trade-off analyses. Crews and Johnson (1974) suggest a nonlinear multivariate regression model as a more appropriate model to describe complex human thought patterns

With respect to public participation, it is difficult to predict the "typical" member of an interest group since all members have different judgment policies. It must also be emphasized that to predict judgments is not to predict behavior since an individual's behavior is situation-dependent. Hence, in any given situation the predicted judgments may not reflect actual behavior. Judgments of citizens are important because they reflect values and beliefs about what should be. They also indicate public acceptance or rejection, but they do not fully predict the consequences of alternative policies.

Other Techniques

The basic technique used in policy capture partakes of both attitudinal surveys and mathematical regression analysis. The closest alternative to a policy capture would be to administer a questionnaire or conduct a survey. However, the policy capture approach has been developed more explicitly than other survey techniques for dealing with the judgmental intangibles and thus is important to policy decisions.

Product or Result

Policy capture makes explicit the priorities and trade-offs among goals. The technique can reveal the relative importance of community goals as well as the diversity of citizen views. It indicates what cues (dimensions) were actually used by the "decision maker" and what importance (weight) was placed on the cues that were used. Mechanically precise calculation of the amount of increase in Category X needed to exactly compensate for a given decrease in Category Y is possible. Furthermore, the discovery of curvilinear function forms implies that trade-offs would not be constant across all levels of spending. For example, the fact that trade-offs among spending categories vary with levels of spending would almost certainly not emerge in public hearings or in written budget recommendations, yet income elasticities are known to be of great importance in making budget decisions (Stewart and Gelberd, 1973).

There are two types of results from a policy capture: participant feedback graphics (illustrating weights and functions), and numerical computations from the regression and cluster analysis. The graphs indicate the relative importance of each dimension of the problem to the person in making his judgments. Large weights (in the form of bar charts) indicate a large effect on judgments of desirability. Small weights indicate relative indifference. Functions (illustrated as plots) show the form of the relationship between the information used to make judgments and the judgments.

Level of Detail

Detail of results reflects the nature of the problem. The method is applicable to both broad and specific issues.

Level of Confidence

The predictive accuracy can be extremely high. Mathematical policy capturing techniques can predict the judgments of the interest group members with an accuracy (correlation) ranging from 0.71 to 0.94 with a median of 0.81. Work by Stewart and Steinmann on consistency and reliability of the desirability judgments indicates that the method is appropriate for a large portion of interviewed people (sample size 173) (Stewart and Gelberd, 1973). Moreover, the results of a number of studies indicate that when "judges" are shown descriptions of the judgment policies of group members, in terms of weights and function forms, then their ability to predict the judgment of others increases dramatically in the specific situation. In short, it is felt that policy capturing procedures can be used effectively to increase understanding. Again, it should be emphasized that the technique, although it models judgments, does not predict behavior.

Communicability of Results

This information is in a precise numerical form that can be presented graphically, understood easily, and used in further analysis. The relative importance of the various problem dimensions, and the trade-offs among them are made explicit. The analysis applies whether trade-offs are constant or vary with levels of dimensions. This approach can result in a significant improvement in the quality and utility of citizen input.

Credibility of Results

Students of the method find it highly credible and can back up claims with data (see comment under "Level of Confidence"). On the other hand, most laymen tend to think their judgments are essentially esoteric and unquantifiable. Such people, unless shown evidence to the contrary, have serious doubts as to the credibility of policy capture.

Resources Needed

Besides an analyst or skilled user, the people requirements are: decision makers who make decisions (judgments) under various sets of conditions. The types of judgments are:

- Binary--yes or no/accept or reject
- Continuous--on some scale, e.g., 1-10
- Rank order.

In its simplest form, the method can be carried out in a matter of days at moderate cost.

Computational backup is required to perform the multiple regressions that are essential to this technique. More elaborate computer techniques are available and are discussed below under "Special Comments."

Special Comments

The full potential of judgment policy capturing can sometimes be realized only with the aid of an interactive computer graphics device. Such a device makes it possible to analyze the judgment policies of one or more people and to display the results immediately. The terminals have been located in public places (such as shopping centers, libraries, retirement homes) for citizens to record their judgments and receive immediate feedback. The program operates with an inexpensive computer terminal linked by telephone to a large timesharing network. The program and user manual, Policy II, are available for Corps use via K. R. Hammond Associates, Boulder, Colorado, 80302 (phone 303-449-8206). Initial costs range from zero to $2,000, depending on the user application.

Procedures

Planners inexperienced in policy capture will require the guidance of a consultant in establishing and carrying out procedure. There is no reason, however, why the planner cannot be an effective--even a directing--participant in such forecasting right from the start.

Case Example

Policy Capture of National Options

Policy capture is used to measure the relative preference of individuals for competing issues. To illustrate the procedure, we present a hypothetical trade-off analysis between national economic development and environmental quality.*

Formulate the Problem--Trade-Off Analysis--In this simple case we assume a situation in which two decision makers (A and B) are faced with the problem of defining a compatible mix between two conflicting issues: National Economic Development (NED) and Environmental Quality (EQ). It is anticipated that a series of alternatives are available in which the two issues are associated.

Select the Issues--Identify and Measure--The issues identified for the trade-off analysis are typically aggregate concepts such as, in this case, economics and environment. In order to use the procedure, numerical measures must be stipulated for each issue. The economic issue (NED) is measured in dollars and reflects the gross national product per capita. NED data range from $1,000 to $20,000. Environmental issues combine aspects of perceived air, water, and land quality. These aspects are aggregated into an environmental quality index with values ranging from 0.1, indicating a foul environment to a utopian environment (0.9).

Develop Alternatives--Generate Scenario--To determine preference, alternative scenarios are developed as probable futures for consideration by Planner A and Planner B. Each future condition describes a possible situation that could exist in the real world

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*This procedure was adapted from a paper by James E. Crews and G. P. Johnson, "A Methodology for Trade-Off Analysis in Water Resource Planning," Journal of Technology Assessment, in press 1975.

in terms of levels of achievement of NED and EQ. For example, average present-day conditions in the United States might be represented by Scenario 5 (Table 22). This scenario depicts a situation in which the GNP per family is $10,000 and there is a relatively high level of environmental quality (0.7). Since policy

Table 22

SCENARIOS WITH PLANNER PREFERENCES

Scenario	Issues: NED	Issues: EQ	Preferences: Planner A	Preferences: Planner B
1	$20,000	0.9	1,000	900
2	17,500	0.9	950	800
3	15,000	0.7	900	500
4	12,000	0.7	825	400
5	10,000	0.7	600	300
6	20,000	0.6	850	300
7	7,000	0.8	500	300
8	13,000	0.6	600	250
9	10,000	0.5	500	180
10	7,000	0.5	400	100
11	12,000	0.4	500	100
12	5,000	0.4	150	90
13	20,000	0.3	700	80
14	15,000	0.3	600	70
15	10,000	0.3	500	60
16	17,500	0.1	325	20
17	7,000	0.2	95	50
18	4,000	0.5	200	30
19	2,500	0.5	150	40
20	1,000	0.9	200	50
Mean	$11,300	0.54	527	231
Standard deviation	5,948	0.237	283	252

capture is based on statistical theories, it is essential that a number of choices or alternatives be available. In this case, 20 alternative scenarios have been prepared.

Rank Preferences--Participants in the procedure score all scenarios in order of preference. It is helpful to use one scenario as a basis for relative scoring. In this case Scenario 5, representing present conditions, was used as a starting point. Planners were instructed to first score Scenario 5, and then score all other scenarios relative to Scenario 5. The preference scores shown in Table 22 could range in value from 1 to 1,000 indicating, respectively, the least preferred scenario and the most preferred scenario. The actual range of numbers used is arbitrary since they are always standardized during the analysis step.

Conduct Mathematical Analysis--The objective of the mathematical analysis is to determine how much each of the two issues contributes to the preference ranking. Thus, a participant's policy is "captured" mathematically by calculating the relative importance (weights) given to each of the issues. A multiple regression equation is used to solve for the coefficients that determine the weights.* In order to compare the weights of different participants, it is necessary to standardize all the numerical values.

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*A simplified multiple regression for this example is shown below. Y indicates preference and W_1 and W_2 indicate, respectively, the weights for national economic development and environmental quality. A detailed mathematical description of regression analysis can be found in most math texts.

$$Y = W_1 \text{ NED} + W_2 \text{ EQ} \quad .$$

Table 23 shows the standardized values and relevant equations used in the multiple regression analysis.

Table 23

STANDARDIZED VALUES*

Scenario	Issues		Preferences	
	NED	EQ	Planner A	Planner B
1	1.5	1.5	1.5	2.6
2	1.0	1.5	1.5	2.2
3	0.6	0.7	1.3	1.0
4	0.1	0.7	1.0	0.7
5	-0.2	0.7	0.2	0.3
6	1.5	0.2	1.1	0.3
7	-0.7	1.1	-0.1	0.3
8	0.3	0.2	0.2	0.1
9	-0.2	-0.2	-0.1	0.2
10	-0.7	-0.2	-0.4	-0.5
11	0.1	-0.6	-0.1	-0.5
12	-1.0	-0.6	-1.3	-0.6
13	1.5	-1.0	0.6	-0.6
14	0.6	-1.0	-0.2	-0.6
15	-0.2	-1.0	-0.1	-0.7
16	1.0	-1.8	-0.7	-0.8
17	-0.7	-1.4	-1.5	-0.7
18	-1.2	-0.2	-1.2	-0.8
19	-1.5	-0.2	-1.3	-0.8
20	-1.7	1.5	-1.2	-0.7

*To standardize the values use the following equation:

$$\text{Standard Value} = \frac{(\text{Value} - \text{Mean})}{\text{Standard Deviation}}$$

For example, the standardized values for Scenario 1 were calculated as follows:

NED = (20,000 - 11,300)/5,948 = 1.5
EQ = (0.9 - 0.54)/0.237 = 1.5

<u>Forecast Preferences and Results</u>--The multiple regression solution calculated the numerical values of the weights for each planner as follows:

$$\text{Planner A} = 0.8\ \text{NED} + 0.5\ \text{EQ}$$

$$\text{Planner B} = 0.5\ \text{NED} + 0.7\ \text{EQ}$$

	Weights	
Issue	Planner A	Planner B
NED	0.8	0.5
EQ	0.5	0.7

For these results it is clear that Planner A and Planner B have different, in fact, almost opposite, policies with respect to economics and environment. While both planners want high levels of NED and EQ, Planner A indicates a clear preference for national economic development (0.8 to 0.5), while Planner B prefers environmental quality even at the risk of lower GNP/family. This means that they have opposite viewpoints, and can be expected to support different programs whenever there is a trade-off between economics and environment. However, further iterations and discussions may lead both planners to agree upon some level of economic development for a high (say 0.6) value of EQ.

In summary, policy capture provides a tool to determine and quantify where differences exist. It can also be used to calculate and evaluate actual trade-off values between issues (Crews, Johnson, 1974). It should be emphasized that this is a numerical procedure and may require several iterations before the participants are comfortable with the preference weights. In other words, one must make sure that Planner A really prefers economic development twice as much as environmental quality. Also, the scenarios presented in this example are hypothetical. Once the weights have been refined, the user should review his options or actual alternatives to see if there is a compromise plan that satisfies both viewpoints. For example, instead of a dam, possibly a channel system would maintain the desired levels of development and environmental quality. Finally, it should be pointed out that the policy capture procedure requires some degree of skill in selecting the issues and developing the scenarios. However, skill in applying the procedure can be readily developed and the mathematical procedures are straightforward and available on computer systems.

Section V

QUALITATIVE AND HOLISTIC FORECASTING TECHNIQUES

Introduction

This section of the report deals with forecasting methods aimed at portraying systems holistically--that is, as a whole. The forecaster typically starts with an intuitive sense of the totality instead of with a specific component of the whole. Typical holistic characterizations of society are "good times," "recession," sick society," "imperialism," "achieving society," "transformational society," and so forth. With the total context in mind, the planner next identifies the elements and how they fit together to make the whole, the driving forces of change, and so forth. At this stage of the analysis, such methods as trend extrapolation and modeling come into play but they are used in the service of explaining the whole. This kind of forecasting thus tends to be more global, more qualitative, and "softer" than more conventional approaches. In general, these are the least developed of the forecasting techniques discussed in the Handbook. Without doubt, however, they represent the areas where the most professional attention is currently being paid. In the opinion of many, qualitative and holistic forecasting techniques are the leading edge of the art and emerging science of looking ahead.

The specific techniques discussed in this section are scenarios and related methods, expert-opinion methods, alternative futures, and values forecasting.

SCENARIOS AND RELATED METHODS

General Description

Abstract

This section discusses scenario and related forecasting methods, including modes and mechanisms of change, authority forecasting, surprise-free futures, and scenarios. It is emphasized that these methods depend upon logical, plausible, and imaginative conjectures that are most properly regarded as descriptions of potential futures rather than as probabilistic forecasts of actual futures. Such methods, like all other qualitative methods, are most often used in conjecturing about complex, little-understood social phenomena for which more rigorous quantitative forecasting methods do not exist.

Definitions

Contrary to our everyday notions (inherited from Descartes and used unthinkingly by all of us), reality is not some fixed, concrete objective existence "out there." Rather, reality is the picture we build up inside our heads to organize and explain what William James aptly called the "booming, buzzing confusion" of raw sensations that stimulate us incessantly. Particular understandings of reality are determined significantly by the language and culture in which our minds develop. For example, one native culture near the Arctic circle recognizes 100 distinct and different types of snow, while in a few cultures no distinction is made between past and future, only between "now" and "not-now."

The notion that reality as we may understand it is one of an infinite number of possible cultural-linguistic definitions may be difficult to comprehend, and unsettling once grasped. The human mind feels an urgent need to believe that it understands how things really are: what things do actually exist, what is occurring, what can occur, and (in consequence) what can exist. An insatiable curiosity and an incessant drive to make sense out of new puzzles when we become aware of them are the essence of being human.

The basis of modern explanations of change is what can be called cause-effect reasoning. The premise of cause-effect reasoning is that whatever happens is the outcome of some preceding occurrence or state of affairs. If only--so goes this line of reasoning--we can discover the cause, we can explain and understand the effect. Indeed, we can hope by understanding the cause to foresee, predict, and even control future occurrences by manipulating or regulating causal factors in the present. This line of thinking inclines the analyst to examine the present and possible futures in terms of modes and mechanisms of change. A mode of change is simply the how or way of change. A mechanism of change refers to the means, instrument, or mechanism in or through which a mode of change is expressed--an airplane, motor vehicle, ship, or spacecraft, for example.

In attempting to forecast the future, unfortunately, many of the modes and mechanisms of change are tortuously complex and obscure. Hence forecasts or efforts to influence the actual future based on complex, obscure modes and mechanisms of change are often in error. When we must rely on imperfect understandings of how complex modes and mechanisms of change operate, we commonly resort to <u>authority forecasting</u>. Pronouncements concerning the future are easily the most common type of "forecast" and can be observed daily in every arena of life.

But why forecast at all when our ability to foresee the future is clearly so limited and inferior? The answer is that we must make plans, investments, and commitments for the future whether or not we can foresee what will actually occur. We therefore must have some basis for making current decisions for dealing with the future. One common way of proceeding in this situation is to assume for planning purposes that the future will be more of the same. That is, we can assume that whatever is not changing today will remain stable in the future. And we can assume that whatever is changing now will go on changing at about current rates and in the same direction.

When we take such an approach we are using what Herman Kahn and Anthony Wiener (in their 1967 book, <u>Toward the Year 2000</u>) labeled <u>surprise-free futures</u>. Such futures are surprise-free not in the sense that we believe they represent the actual future. Rather, such images of the future are surprise-free in that they assume no sudden discontinuities or revolutions that would make the future bear little resemblance to the past or the present. When we can see that the present projected into the future may with equal plausibility develop in two or more different directions, we can explore each direction separately. In this case, Kahn and Wiener would say that we are exploring <u>canonical variations</u> on the surprise-free future.

But how can we express or put down in an organized fashion our conjectures about how given modes and mechanisms of change projected into the future might result in particular surprise-free futures or variations on them? One of the most commonly used techniques for this purpose in futures forecasting is the scenario. A scenario is nothing more than an outline of one conceivable state of affairs, given certain assumptions about the present and the course of events in the intervening period. The term scenario originally referred to the bare outlines of a script for a film or a stage play. As used in the futures forecasting field, a scenario remains essentially a product of the yarnspinner's art, whether the yarn takes the form of narratives, numerical tables, or graphic projections. It is important to note that scenarios usually are portraits of possible futures rather than predictions of what will come to pass.

Assumptions

The various types of methods mentioned above have different underlying assumptions. For example, analysis of modes and mechanisms of change presumes that the future can, in fact, be foreseen in these terms. The authority often secretely assumes that s/he, and s/he alone, knows. The basic assumption of surprise-free techniques is plain from the name itself. Finally, scenarios are prone to be written by people who sincerely believe they can imagine the way the future will be--this despite the fact that all previous forecasters in history have failed to foretell the emergence of events that have critically shaped the future.

History

Invocation of modes and mechanisms of change to explain the present and foresee the future is as old as human thought itself. Naturally enough, the content, power, and sophistication of modes and mechanisms drawn upon has evolved with the human mind. For example, weather forecasting has developed from the simple-minded "red in the morning sailors take warning; red at night, sailor's delight" to the use of elaborate numerical models and satellite photography.

As always, development of improved modes and mechanisms to explain and predict change has progressed more rapidly in some fields than in others. Many explanations of physical changes, for example, have become quite powerful and reliable, opening the way for modern physical technology. In other instances--notably in the fields of psychological and social phenomena where the need to predict and control is great--explanations and understandings remain limited. It is for that reason that resort to authority forecasting, as already mentioned, remains commonplace today. On the other hand, it is precisely because even the "authorities" are in error more often than they are correct that the search for improved explanatory models has been pressed in recent years. Scenarios, for example, assume that the actual future remains elusive and that it therefore is necessary to explore a range of potential futures, with the hope that the actual future will in some sense be bracketed. As a formal means of looking ahead, scenarios are a product of the 1960s. As an informal means, taking such forms as utopias, dystopias, and much science fiction, scenarios go back to the days of Sir Thomas More (1478-1535).

Main Uses

The limited reliability and accuracy of scenario and related methods to predict the actual future have been emphasized repeatedly. From this, it follows that such methods are normally used where the need to conjecture about potential futures is thought to be urgent and important but no more exact methods are available. Given the present and future importance of social, economic, and political issues and the status of the behavioral and social sciences, it is in these fields that scenario methods are most commonly used. Scenarios are also helpful in "freeing up" a planner's conventional vision of reality. Scenario methods can be and have, in fact, been used in other applications--for example, in technological forecasting--but more rigorous methods have been developed for such purposes, and they are preferable whenever their use is feasible.

Limits and Cautions

In the presence of phenomena that intrigue us but that we do not understand, we humans have an ancient tradition of "making up" plausible explanations, then accepting such plausibilities as truths. The scenario writer--and his audience as well--is all too apt to slip into what dramatists term the willing suspension of disbelief. That is, we are apt to accept "good" stories about the future as forecasts of the actual future. Symptomatic of this is the tendency within a set of scenarios exploring a range of potential futures to look for the one that is the real forecast. Developers and users of scenario methods cannot be too often or too strongly cautioned about this tempting abuse of scenario methods. The other side of this coin is the power of a negative scenario to sensitize people to the dangers of its occurrence. Orwell's 1984, for example, is less likely to happen because of the graphicness of the scenario.

Other Techniques

The other principal techniques for future forecasting that are most interchangeable with scenario methods are described in subsequent sections of this Handbook. They are:

- Expert-opinion methods
- Alternative futures
- Values forecasting.

Product or Result

In any but the most trivial forecasting effort using scenario and related techniques, the final result will include a formal document recounting topical definition, assumptions, procedures, data used, findings, and interpretive comments. Depending on which combination of the methods discussed here is used, this document will cover some or all of the following major points:

- Identification and discussion of the major modes and mechanisms of change invoked and applied in making the forecast.

- The credentials of the authority (or authorities) whose opinion is cited, a statement of procedures followed, information used, and an analytic interpretation representing the authority's best judgment about possibilities, probabilities, and crucial factors.
- A summary or a detailed projection of what the surprise-free future would be like, together with an identification and at least some treatment of canonical variations on the surprise-free future, if any of major importance are uncovered.
- Any or all the above may be in addition to or incorporated in the text of two or more scenarios describing plausible potential future courses of development or evolution from the current state of affairs.

It perhaps also should be pointed out that the very process of imagining, working out, and discussing scenarios often produces insights and sensitivities at least as significant to the planner as the more concrete outputs from the exercise.

Level of Detail

Results are almost always broad in scenario-type forecasts although supporting data may be highly detailed. Authority forecasts are more likely to have a narrow focus than other types of forecasting.

Level of Confidence

As forecasts, scenarios should command little respect for accuracy, completeness, or validity because such methods are used most often when the underlying modes and mechanisms of change are not well understood. As useful, logical, and plausible conjectures, scenarios can be evaluated according to the values, insights, and information of their critics. In turn, the competence and qualifications of a given critic may be and are evaluated on precisely the same basis by other critics.

Communicability of Results

Because scenarios can be expressed in the form of coherent, plausible stories, they constitute perhaps the most communicable form of futures conjecture. Indeed, scenarios are frequently accepted as forecasts of the actual futures precisely because their reasoning seems so logical and plausible, while the use of rich typical details can convey the "tang" of substantiality that often is lacking in the products of other forecasting methods.

When authority forecasts or descriptions of surprise-free futures are presented not in the form of scenarios, they may tend to be esoteric and jargon-filled, and hence less communicative than scenarios.

Credibility of Results

The credibility of the results of scenario and related methods varies widely from topic to topic, study to study, and audience to audience. When the method is essentially that of authority forecasting, the authority's credibility may be extremely high in one situation and extremely low in another. When the emphasis is on surprise-free futures, what is surprise-free to one audience may be shocking, illogical, and totally unacceptable to another--reflecting differences in values, assumptions, and knowledge. As mentioned repeatedly, scenarios are often given more credibility than they deserve, because of their powerful literary ability to convey an (often unwarranted) sense of insight, knowledge and validity.

Span of Forecasts

The future time horizon of scenario and related methods is wide indeed. These methods may be used over as broad a period as assumptions, data, and logical plausibility can support. Reflecting the fact that these methods are most often used to forecast complex or obscure phenomena, the forecasts tend to be long range--five years and more. Scenario-type methods are particularly well adapted to looking ahead for very long periods--say, 50 years and more.

Resources Needed

Like most qualitative methods discussed in this section of the Handbook, scenario and related forecasting methods can be used with fewer resources than almost any other forecasting approach requires. This is because qualitative methods can be and most often are used not to predict the actual or most probable future but rather to explore a range of potential futures. So used, scenario methods do not require the extent or quality of data and analysis needed when the object is to foresee the most probable actual future. When prediction is the intent--especially in the authority method--resource requirements may still be less than for other methods, or they may be comparable, depending primarily on how much work has been done how recently by others in the same or in closely related fields.

On the other hand, these kinds of methods place great demands upon the analyst's powers of imagination, originality, and capacity to break free of conventional assumptions about the future. In addition, an effective scenario writer has need of considerable literary capacity.

Procedures

Anyone gifted with an imaginative turn of mind and a sense of how events fit together into a whole--and this means anyone free enough to want to spin stories about the unknown--can be a scenarioist. Easy as scenario-generation is, planners conducting formal, systematic studies will want procedural help from experts. In addition, most planners, in order to introduce as firm a data base as possible, will want extensive inputs from the various publics affected as well as from specialists in the trends incorporated into the scenario.

Case Example

Scenarios of Future Growth Patterns

Essentially a story, a scenario may be developed in many different ways. Most approaches, however, involve some common basic steps. These basic steps are well illustrated in an imaginative application of the scenario method made by the Corps' Omaha District Regional Planning Branch. The four scenarios generated are presented in a report designed for the widest possible dissemination and use in the region. Bearing the full title This Land is Your Land, it will for brevity be cited hereafter simply as This Land* ....

In the following paragraphs, we list eight basic steps typically taken in developing any scenario, and explain each step in terms of This Land ... as an actual example.

(1) Identify and Describe the Users and the Uses of the Scenarios

This Land ... identifies the cities and agencies participating in the Urban Study Program. As the participants in the program and the ultimate plan evolving from it, they are the target audience for the scenarios. Among the many parties cited in This Land ... are the cities of Omaha, Council Bluffs, and Bellevue; the Metropolitan Area Planning Agency, Iowa Department of Environmental Quality; the Nebraska Office of Planning and Programming; and many others.

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*THIS LAND IS YOUR LAND: Water resources management alternatives for the Omaha-Council Bluffs area. Introduction and Alternative Growth Potentials - Volume 1. Omaha District Regional Planning Branch, U.S. Army Corps of Engineers, 6014 U.S. Post Office and Court House, 215 North 17th Street, Omaha, Nebraska 68102, 1975, 20 pages.

In Phase I of the Study Program, factors affecting the region's water and water-related land resources were investigated in depth. Pertinent concerns, opportunities, and constraints bearing on potential solutions were also examined carefully.

Phase II involved developing the alternative scenarios presented in <u>This Land</u> .... While the scenarios in this study were limited to exploring alternative patterns of future growth in the region, subsequent sets of scenarios deal with waste water, water quality management, water supply management, water-related recreation, flood control/flood plain management, and water and water-related land resources.

(2) <u>Select a Time Horizon Suitable to Project Requirements</u>

In this instance, the time horizon had been previously selected for the Urban Study Program overall, namely the period 1970-2020.

(3) <u>Select a Territorial Scope Suitable to Project</u>

Here, again, the boundaries of concern had already been established by the program. They include Washington, Doublas, Sarpy, and Cass counties in Nebraska; and Harrison, Pottawattamie, and Mills counties in Iowa.

(4) <u>Select Critical Issues to be Treated in the Scenarios</u>

Once again, these issues had already been selected in Phase I of the program, and were listed above in Step 1. Once again, the reader is reminded that *This Land* ... scenarios were limited to exploring future growth alternatives. Other sets of scenarios were scheduled in turn to deal with each of the major issues mentioned earlier.

(5) <u>Select Basic Topics to Be Treated in the Scenarios</u>

This Land ... singled out the following topics for attention:

(a) Possible social and economic trends in the nation and the Midwest as applicable to the study area.

(b) Alternative forms of future urban growth discussed in studies of other, comparable metropolitan areas.

(c) The expressed goal aspirations of citizens, organizations, and planners throughout the study region.

(6) <u>Compile and Organize a Data and Information Base to Be Used in Developing the Scenarios</u>

Phase I of the Urban Study Program had already developed the data and information base required to write the scenarios. In this case, the necessary investigation had been done under contract by Dana College, Blair, Nebraska.

(7) Determine the Scenarios to Be Developed; Write and Circulate Review Drafts

The following four scenarios were developed for This Land ... :

Growth Concept A--Projection of current land-use trends in the region.

Growth Concept B--Controlled expansion of urban Omaha, with emphasis on higher density residential development, revitalization of the urban core, and development of satellite cities.

Growth Concept C--Similar to Growth Concept B, except for the omission of satellite city development.

Growth Concept D--Similar to Growth Concept A, except for the assumption that much development will occur in fingerlike projections along the major transportation corridors.

In draft form, these scenarios were circulated, reviewed, and critiqued by appropriate committees and others representing Urban Study Program participants. Final revisions were made by the project team and the excellent report, This Land ... was published.

(8) Distribute the Scenarios to All Users

This Land ... has been widely distributed to cities, agencies, organizations, and private citizens throughout the region. All recipients have been invited to express their preferences among the four alternative growth concepts presented, and told how to register their preferences with the project team. Apart from individual expressions of opinion, <u>This Land</u> ... also affords an excellent, readily usable vehicle for workshops and other organized solicitations of opinion from interested groups throughout the region.

EXPERT-OPINION METHODS

General Description

Abstract

This section discusses forecasting via expert-opinion methods, including the use of panels, surveys of intentions and attitudes, and Delphi polls. It is emphasized that the definition of expertise as well as the limits to its use for forecasting purposes can be considered in terms of three aspects: topic, sponsor, and other eventual users of the study's end-product. Expert-opinion methods may be used either for actual forecasts or to make conjectural explorations of potential futures. Identifying, qualifying, and making pertinent experts credible is a central issue with these methods. While the findings of expert-opinion studies are usually easy to communicate, it is often difficult to convey the specialized information and the reasoning on which findings are based.

Definition

Expertise must surely be among the service commodities most widely and variously bought and sold in contemporary society. Ranging all the way from advice on how to grow earthworms at home for profit to a consultant firm's reorganization of the Bank of England, expert opinion and advice is an essential lubricant.

Granted that expert opinion is both essential and pervasive in modern times, it may seem surprising that insights into the nature and proper uses of expertise remain in such a primitive state.

One simple way to clarify the nature of expertise is to inquire: <u>expertise relative to what</u>? A simple, three-way breakout in answer to the question sheds some useful light. Expert opinion may be defined and assessed relative to:

- Its topical object
- The sponsors of expert-opinion studies
- The end-users of expert-opinion studies.

The supply and accuracy of expert opinion relative to any given topic increases as the topical scope narrows, topical complexity decreases, and well-understood principles and theories can can be invoked. By the same token, the supply and accuracy of expertise decreases as these aspects of a topic shift in the opposite directions. It is clear, for example, that far fewer people are able to make reliable forecasts for the 50-year future of surface transportation in the United States than can usefully predict future trends in, say, the narrower segment of barge traffic.

One means of assessing the supply and worth (assuming that worth and accuracy of forecast are positively related) of expert opinion about the future, then, is to relate it to the scope, complexity, and theoretical foundations of the topic. A different, second route to the same end is to assess expertise by contrasting it with the worldviews and intents of whomever is willing to buy and pay for such opinion. The future of automotive technology can serve as an illustration of this point.

If an automobile manufacturer is sponsoring a forecast of automotive technology for the next 50 years, certain types of expertise and certain experts will be held pertinent, competent, and credible. If the same study were to be sponsored by the National Academy of Engineering, the Office of Technology Assessment, Common Cause, or the Sierra Club, the expertise judged relevant would be the same in certain instances and different in others. The sponsor's experience, understanding, and motives significantly affect what expertise is held important.

In addition to the specificity of a topic and the character of a sponsor, the identity of the eventual forecast end-user (specific publics in the case of Corps projects) influences who is considered expert. This third aspect of the matter actually is implied in the preceding paragraph. In framing legislation pertinent to automotive technology, Congress has purposes and requirements substantially different from those of auto manufacturers in planning its research program for the years ahead. Oil companies, companies proposing alternative propulsion systems, and conservationist groups have still other motives.

Thus, before one can answer the deceptively simple question, Who is Expert, the questions of forecast topic, sponsor, and end-user must be addressed in each particular instance. Because these three different perspectives are seldom identical, consensus on the pertinence, competence, and credibility of experts to be consulted is seldom if ever attained. Organizations desiring to employ expert-opinion forecasting methods should be forewarned of the issues raised here, and should make specific provisions in advance for dealing with them.

Given such general comments about expert-opinion methods, three specific methods of this type are discussed in this section.

Panels are selected, organized groups of persons thought to have in common an exceptional degree of expert knowledge or opinion about some designated topic. Panels may be informal, ad hoc, one-time-only groups meeting face-to-face to hammer out a consensus. Many other variations are possible, including extremely formal, continuing groups which--as in Delphi panels--may never meet face-to-face.

Surveys of Intentions and Attitudes represent one specific application of opinion polling or survey research techniques. Such surveys seek to clarify the opinions within a specified population concerning its priorities or intended future behavior. In this instance, the people involved are regarded as the only experts on their own attitudes and intents. Surveys can, of course, deal with national samples, various subsamples, international opinion, and so forth.

Delphi Polling and related methods are another specific application of opinion polling and survey research methods. In this technique participants do not meet and are not identified until the poll has been completed, so as to minimize the influence of "big names" and dominant personalities. The use of mail removes limitations of geography in selecting panelists. In Delphi polls, expertise may be equated with special knowledge about a topic, informed opinions about the attitudes and intents of some population, or both. Unlike surveys of intentions and attitudes, in Delphi polls individual participants are given one or more opportunities during the study to compare and (if s/he chooses) revise her/his estimates. Typically, Delphi polls involve far fewer participants than public surveys, partly because of the greater demands made on Delphi participants and partly because of the greater complexity and cost of Delphi studies.

Assumptions

As implied by the preceding disucssion, the primary assumptions on which expert-opinion methods are based include that:

- The forecast topic can be delineated in sufficient detail to make possible the identification of pertinent experts.
- The nature of the topic is such that persons whose knowledge and experience are especially pertinent to the topic are better able than others to predict the probable future course of developments.
- A representative sample of qualified experts can be tapped to participate in the forecast or study.
- The qualifications of the experts selected will be accepted both by the sponsors and by the ultimate users of the forecast, when these parties are not the same.

History

Rousseau once observed sarcastically that "the first priest was the first rogue who met the first fool." Given the vague, subjective nature of expertise and the universal human need to minimize uncertainty, one might substitute <u>expert</u> for <u>priest</u> in Rosseau's aphorism. In any case, kings, generals, and powerful persons of all descriptions have always relied on trusted advisors presumed to be experts in their respective fields. Today, corresponding roles are played by corporate and government agency staffs, academics, research organizations, and consultants of every description. Resort to panels and Delphi polls as explicit, specialized methods are of more recent vintage. The use of consumer panels to pretest products and the use of panel discussions at meetings, conventions, and colloquia are essentially developments of the 20th century. Opinion polling and survey research have their modern origins in the rise of mass communication media, the interest of politicians in popularity ratings, and the rise of mass national markets associated with the post World-War-I era. Delphi polling, as a distinctive application of survey research methods, was developed and first used for the Department of Defense by the RAND Corporation in the 1950s.

Main Uses

The main uses of expert-opinion forecasting methods are conveniently subdivided into two types. In one type, the experts consulted are recruited because of their extensive special knowledge about a topic. Examples would be a panel forecast of the prospects for nuclear fusion power, or a Delphi forecast of economic growth using selected econometricians as participants. Subject matter in these kinds of studies ranges from the broad to the highly specific and narrow.

In the second type, participants are recruited because they are deemed representative of a subpopulation whose opinions or intentions for the future constitute (or influence) the forecast topic. Examples would include presidential-preference opinion polls or the widely respected surveys of consumer spending intentions conducted regularly by several organizations. As a rule, specifically technical questions are not included in public opinion studies, but, otherwise topics can range from the global to a pinpoint issue.

Limits and Cautions

When introducing the definitions of expert-opinion methods, we suggested that expertise can be characterized relative to a study topic, study sponsor, and end-product users. Limits and cautions to these methods are conveniently considered under the same headings.

Perhaps the most difficult and least appreciated aspect of these methods is the problem of defining appropriate topics to forecast. No matter what method is used, the final results will have a limited value if the topic was inadequately defined at the outset. In expert-opinion methods, the importance of adequate topic definition is particularly crucial, not only because the identity and pertinence of experts to be consulted hinges on the definition, but because one needs to be certain that the experts share the same notion of what they are forecasting.

Sponsors organizing an expert-opinion futures study should take special care to define and program two items: how the end-product is to be used, and how it is to be assessed. Expert opinion can be expensive, and it is foolish to implement a substantial study before it can be shown who is going to make what use of the result to what end when the study is completed. By the same token, objective criteria for weighting the study findings and implementing their implications should be thought through before the study begins. Otherwise, an unanticipated conclusion may become a source of endless wrangling and delay. If there is any reason to suppose that knowledge of the name of the sponsor would skew responses of the experts, the sponsor's identity should remain secret until the poll is completed.

If an expert-opinion study is to be available to or used by parties other than its immediate sponsor, it is essential to define the purpose(s) of the study from the start so as to avoid misunderstandings and disappointments. For example, a study may have as its object an exploration of potentials, a probabilistic forecast of the expected future, or some combination of the two. A study intended to serve as a forecast must meet more rigorous standards than a merely exploratory study. On what basis was the particular method used selected? How were experts identified and assessed? What criteria for content and credibility will the forecast's intended audience insist upon? These and related issues must be raised and resolved before the project begins, and not when the forecast findings are challenged after the fact.

Other Techniques

The other principal techniques for futures forecasting that are most interchangeable with expert-opinion methods are the allied holistic forecasting methods--scenarios and alternative futures.

Product or Result

The scope, formality, and effort-level of expert-opinion forecasting methods vary enormously, and the end-product or result varies accordingly. The result may amount to little more than a 25-word oral reply to a casual inquiry made of an expert in the course of some other interaction with a client. At the other extreme, a major, intensive Delphi study might yield a 200 to 300 page final report, including raw data for each round, elaborate statistical analysis, and many pages of interpretive comments.

Level of Detail

As indicated above, detail in these kinds of forecasts can range from unsupported conclusion to elaborate statistical analysis.

Level of Confidence

The range of confidence is great. It depends not only on the nature of the topic and available experts, but on whether the kinds of considerations sketched above in "Limits and Cautions" are taken into proper account.

Communicability of Results

The communication of expert opinion is perhaps one of the most controversial topics in modern society. Complexity and specialization combine to create a situation in which the more expert an opinion is the less intelligible it becomes to others. In expert-opinion forecasts or studies, the findings and conclusions usually can be conveyed well enough. On the other hand, the information and the reasoning on which the findings and conclusions are based may be essentially incommunicable. Whenever a study's findings are unpleasant or inconvenient, a stage is set for endless debate and dispute about the validity of the study.

Credibility of Results

This aspect of expert-opinion forecasting is sufficiently discussed above in "Definition" and in "Limits and Cautions." The key question is, Credible to whom?

Span of Forecasts

A forecast or futures study based on expert opinion may embrace any time span an acknowledged expert is willing to treat and a sponsor finds credible. Speaking practically, however, time spans are determined by the topic and by the minimum interval required for significant changes to be experienced. For example, an expert-opinion forecast of future automotive technology might embrace a time span of the next 10 to 30 years. By contrast, surveys of consumer buying intentions typically range between the next few months and the next year. Or again, forecasts treating the future of societal institutions may consider prospects for the next few generations.

Resources Needed

Like other qualitative methods, the scope, sophistication, and so the cost of expert-opinion studies vary widely from one situation to another. Where a single expert is asked to provide a casual estimate of limited scope, a minute of time and little or no cost may be involved. Where a substantial panel, polling, or survey is required, costs totaling $10,000 to $50,000 or even more may be sustained. Typically, significant opinion or Delphi studies require several months to plan, implement, and analyze.

Major polling efforts require researchers familiar with questionnaire and survey design plus basic statistics. Survey results are often computerized for ease of manipulation. The Delphi procedure involves much clerical and paper work and careful attention to exact phrasing and rephrasing of responses of panelists.

Procedures

As in scenario techniques, the planner's need for expert assistance ranges from essentially none (if s/he is the expert) to extensive, if numerous trends are involved. With respect to procedures, this situation is similar: simple panel procedures are familiar to everyone; in contrast, it would be foolhardy for an inexperienced planner to attempt a major Delphi study without expert guidance.

Two illustrations of expert-opinion procedures are given below. The first describes an extensive Delphi study and the second a hypothetical "mini-Delphi" procedure that could be useful in a conference setting.

Case Examples

The AWR Delphi Study

A Delphi poll on the future of American Water Resource (AWR) utilization and development was conducted during 1972 for the Institute for Water Resources.* For brevity, we shall hereafter refer to this study simply as the AWR Delphi. This example of a Delphi poll is discussed in terms of a sequence of seven basic steps common to most Delphi studies. These steps are:

- Identify and describe users and uses of the Delphi poll results.
- Select topics or issues for study.
- Recruit qualified participants for Delphi poll.

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*Report of Delphi Inquiry Into the Future of American Water Resource Utilization and Development. Minneapolis: Office for Applied Social Science and the Future, University of Minnesota. January 15, 1973, 56 pages plus two extensive appendix volumes.

- Prepare and mail Round One Questionnaire.
- Analyze Round One returns, and prepare and mail Round Two.
- Analyze Round Two returns, and prepare and mail Round Three.
- Analyze Round Three results and prepare final report.

In describing the AWR Delphi, actual findings are referred to only to the extent necessary to make clear the procedures followed. Readers interested in the substantive outcomes of the AWR Delphi are referred to the final report, already cited.

Identify and Describe Users and Uses--The ultimate users intended by IWR in sponsoring the AWR Delphi included all Corps organizations and individuals concerned with water resources planning, together with their consultants, contractors, client governments, and coordinate organizations such as Department of Interior and Bureau of Reclamation.

The intended use was for background, exploratory study purposes. Corps projects in recent years have regularly encountered sudden, unanticipated delays and opposition. Believing that a substantial factor behind these difficulties was a difference in values and preferences among various stakeholders, IWR hoped that the AWR Delphi might shed some useful if tentative light on this important topic. Such insights, in turn, would be of immediate practical value in ongoing water resources project planning.

Select Topics or Issues for Study--The AWR Delphi focused on the interrelations and interactions between two broad topics: American values, value differences, and value changes on the one hand, and present and future water resources problems on the other.

A register of American values prepared in earlier work by Baier and Rescher (1969) was used in designing value questions for the Delphi poll. In all, 42 important American social values were included, organized under six main headings: (1) oneself, (2) one's group, (3) society, (4) the nation, (5) all mankind, and (6) the environment. As an illustrative example, the values listed under Oneself included personal material welfare, self-respect, self-reliance, personal liberty, self-advancement, self-fulfillment, and skill and prowess.

In turn, each of these individual value items was characterized in a few words. For instance, self-respect was characterized as: "the right to be treated as a person and as a member in good standing of the community; honor, honorableness." In a few cases, even these individual value items were further subdivided.

American values was one of two broad topics explored in the AWR Delphi, the other being water resource problems. For this second topic, a different approach was taken. Rather than using an exhaustive typology of water resources problems, the AWR Delphi project team singled out seven individual problems judged to be of special importance. The seven problems cited were:

(1) Demand for and abuse of water resources resulting from increasing affluence.

(2) Demands on water resources resulting from energy consumption.

(3) The relative rights and responsibilities of federal, regional, state, and local authorities, and public and private interest groups in planning and managing water resources.

(4) Public confidence in officials (including technical specialists) and in the information they provide, regarding planning, managing, and using water resources.

(5) Demand for waterborne transportation requiring additional port facilities that encroach upon and pollute water and contiguous land resources that otherwise could be devoted to wilderness, recreation, aesthetic, and other uses.

(6) Reduction in the availability of beaches and shorelines due to erosion or private use, or both.

(7) Population mobility and consequent public apathy toward water resources decisions of the community.

Recruit Qualified Participants--In making a Delphi futures study of the evolving relations between two such broad topics, rigorous and clear-cut definition of qualified participants was difficult. This is a problem regularly encountered in using the Delphi poll method for topics other than those whose scope can be narrowly and rigorously defined. After due consideration, the AWR Delphi project team adopted the following definition of qualified participants: "Persons whose occupations and activities seem likely to influence the future development and utilization of water resources, as well as those more conventionally acknowledged to be specialists in the field."

Drawing on their respective knowledge and experience, the project team members developed a list of 280 potential participants in the AWR Delphi, and invitations were extended. In due course, 124 persons agreed to participate, the others declining for a variety of reasons.

(As a side note, participants in the AWR Delphi were not remunerated for their services. This is a standing issue in using the method. Some parties contend that remuneration invariably distorts the sampling of experts involved, while others argue that it is unrealistic and unfair to require extensive effort from well-qualified specialists without compensation. In general, participants are often willing to serve without compensation if the issue is of public significance or if their personal interests are affected; compensation is usually expected if the work is for the benefit of a profit-making enterprise.)

Proceeding slightly out of sequence for a moment, biographic data about the 124 participants were gathered in Round One. Three judges independently then categorized each participant. In this way, a list of categories of participants was devised and applied in all three rounds of the AWR Delphi, enabling the project team to track any shifts in the composition of participants, round by round. Seven categories were used:

- General academics
- Water resource academics
- General government representatives
- Water resource government representatives

- Commercial representatives
- Private and public interest group representatives, including individual private citizens
- Consultants

Prepare and Mail Round One Questionnaire--Round One was limited to exploring the register of American values already described. With subdivisions in some cases, 42 values comprising 72 items were provided, for each of which participants were asked to give forecast estimates. (As mentioned earlier, biographic data on the participants was also gathered with the Round One Questionnaire.) Item 1 on the Round One Questionnaire, together with the reply column headings, is reproduced in the tabulation below.

(check one column for each item)

	Probably less important than today	Probably more important than today	Probably same importance as today	No Answer
Self-oriented values				
1. Personal material welfare (the right to life and the pursuit of happiness)				
A. Health (physical and mental well-being)	_____	_____	_____	_____

Following prescribed Delphi procedure, the 72-item ballot was mailed to the 124 persons who had agreed to participate in the AWR Delphi. In due course, 100 usable Round One Questionnaires were returned to the project team.

Analyze Round One Returns and Prepare and Mail Round Two--Compared with Rounds Two and Three, assessment of the 100 Round One Questionnaires returned was relatively simple. The task was to estimate the nature and extent of agreement among the participants as to probable future changes in American value priorities. Index values were assigned to the individual reply columns as follows:

Probably less (-1); probably same (0); and probably more (+1). These index values for each item were then added together and divided by the number of replies to arrive at a change index value for the item.

Next, the range of change index values was itself divided into seven intervals, and an interpretative significance assigned to each interval, as shown below:

A change index of:	Is interpreted as meaning:
+0.5 and greater	Significant positive change
-0.5 and smaller	Significant negative change
+0.35 to +0.49	Probable positive change
-0.35 to -0.49	Probable negative change
+0.25 to +0.34	Possible positive change
-0.25 to -0.34	Possible negative change
-0.24 to +0.24	Significant change not likely (if at least half of all replies were "probably same")

For 16 of the initial 72 value items polled in Round One, there was no clear consensus. It was decided to repeat these items in Round Two to see if a consensus could be attained.

In Round One, respondents suggested three other, environmental values as being important. The AWR Delphi project team decided to include these items in Round Two, as follows:

- Compatibility between ecosystem and human system functions.
- Regard for natural resources.
- Regard for all forms of life.

In accordance with Delphi procedures, a summary of Round One results was mailed to all respondents shortly before Round Two was mailed. Included with each summary was a computer printout showing the individual respondent's position on each item. This enabled each participant to compare his replies against the medians and interquartile responses for all participants, which were given in the Round One summary. (An interquartile range simply shows the value <u>below</u> the median that encompasses one-quarter of all replies, and the value <u>above</u> the median that encompasses a second one-quarter of all replies.)

Thus, one portion of the Round Two Questionnaire was again devoted to values: 16 values for which consensus had not been attained in Round One, and three new values proposed by Round One respondents.

The major portion of the Round Two Questionnaire, however, was devoted to the seven water resources problems listed in discussing the selection of topics earlier. For each of the seven problems, participants were asked to give three estimates, as follows:

- Importance ranking--Participants were asked to assign the numbers 1-7 to the problems, using 1 for the most important.
- Timing--"With current trends, when will the problem be a national issue: Now? In 5 years? In 10 years? In 20 years? Later? Never?"
- Action timing--"When should action be taken at the national level?" (The same timing intervals as above were used.)

Finally, in an open-ended portion of the Round Two Questionnaire, participants were asked to suggest effective actions that could be taken to deal with the respective problems.

The Round Two Questionnaire was mailed to the 100 persons who had returned Round One; 74 replies were received by the project team.

Analyze Round Two Returns and Prepare and Mail Round Three--Of the 16 values resubmitted in Round Two because no consensus was reached in Round One, a consensus was reached on 11. The remaining five were excluded from further consideration in Round Three. The three environmental values submitted for the first time in Round Two were all judged by participants to be of growing importance in the future.

Figure 29 shows a summary of future estimates for each of the seven water resources problems posed in Round Two. As usual in Delphi summaries, median replies with interquartile ranges are shown.

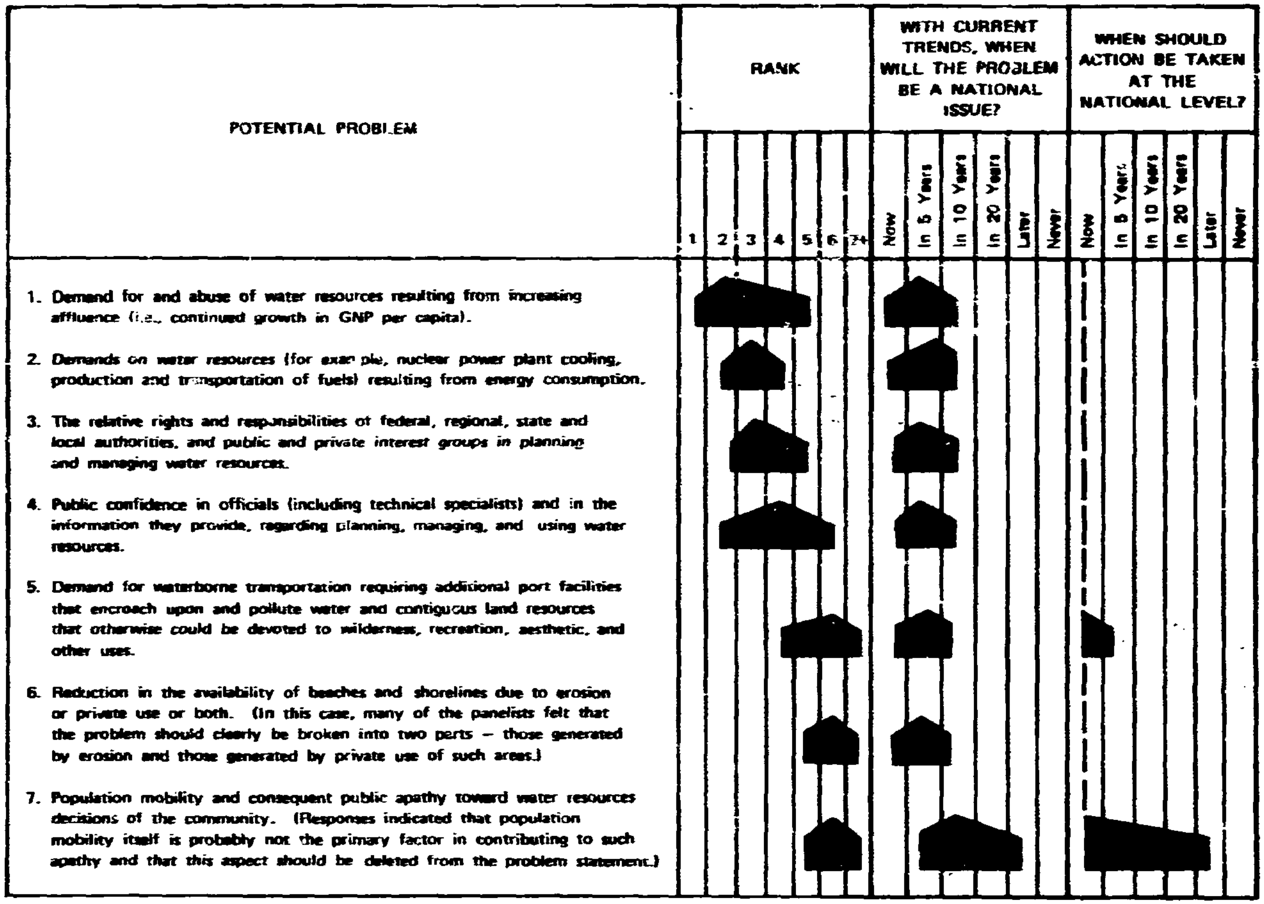

FIGURE 29 WATER RESOURCE ESTIMATES, ROUND TWO

The open-ended portion of the Round Two Questionnaire drew a wealth of responses, a typical experience in Delphi polling. As the AWR Delphi final report explains:

> More than 50 suggestions were obtained for new problems, and panelists submitted more than 110 new events, of which about 40 were for the original problems, with the remainder associated with new-problem submissions. More than 250 new actions were obtained, with about 160 of these related to the original list of problems. In some cases, problems offered by panelists seemed to be more nearly events and actions than problems, and some reorganization of that material was performed in the preparation of Round Three forms for assessment by the entire panel. ... The presentation of this material required lengthy and complex forms.

This "lengthy and complex" form is just that--49 oversized pages of detailed questions asking respondents to make estimates under each of six main headings, with further subdivisions in some cases:

- Potential problems
- Timing of potential problems
- Possible related events
- Suggested actions
- Timing of actions
- Value conflicts.

In addition to this 49-page questionnaire, Round Three participants were also set a separate task involving the analysis of the problems presented in tentative sets on individual cards. This separate second task is of real interest, but it created special problems and is not typical of a Delphi poll and so is not discussed here.

A summary of Round Two results was also prepared and, together with Round Three, was mailed to the 74 participants who had returned Round Two. In due course, 51 usable replies to Round Three were returned to the AWR Delphi project team. To recapitulate participation:

Round	Mailed	Usable Returns
1	124	100
2	100	74
3	74	51

Such a decline in participation as a Delphi poll proceeds is not unusual, and should be anticipated in planning such a project. The extent and complexity of the task is often underestimated at the outset by all parties. As the true nature of the task is revealed, many participants are unable or unwilling to continue. The project team might have maintained a higher level of participation by reducing the richness, but probably was reluctant to do so because of its original commitments to participants and because of the team's own keen interest in the study content.

Analyze Round Three Results and Prepare Final Report--In assessing Round Three, the AWR Delphi project team concentrated on what it labeled high-response events and high-response actions for each of the potential problems. High-response was defined to mean events or actions for which no more than 25 percent of all participants assigned a never or a no-answer estimate.

A categorized tabulation of high-response events is given below;

Category	High-Response Events	
Technological	15	(27.7%)
Socioeconomic	16	(30.0%)
Water depletion or scarcity	8	(14.8%)
Growth and its consequences	4	(7.4%)
Government action	4	(7.4%)
Major disasters	3	(5.5%)
Miscellaneous	4	(7.4%)
	54	(100.0%)

A comparable tabulation of high-response actions follows:

Category	High-Response Actions	
Government control	49	(34.2%)
Research and development	37	(25.9%)
Increased public education/ participation	21	(14.6%)
Planning, goal setting, formulation	16	(11.2%)
Actions by professional/ government water resources personnel	12	(8.4%)
Miscellaneous	8	(5.6%)
	143	(100.0%)

Having analyzed Round Three results, the AWR Delphi final report was prepared and distributed through the project team to all participating parties.

"Mini-Delphi"--Delphi Simplified for Small Groups in Conference

Although the Delphi technique is generally considered time consuming and highly complex, the concept in modified form can be made relatively quick and simple for use in a conference setting. The example described below is derived from CERL Technical Report D-13, December 1973, "Environmental Impact Assessment Study for Army Military Programs." The example has been rewritten to put it in terms of a civil works planning situation.

The hypothetical problem considered in this example is to obtain a consensus on the relative importance of a number of environmental impacts of a reservoir under study. The participants could be the study team, a citizen panel, an environmental group, and so on. In selecting participants, it is wise to follow some general guidelines for establishing an effective panel:

- Select members with a diversity of pertinent specializations.
- Select members of approximately equal status.
- Avoid a member who is likely to try to dominate the panel.
- Provide for rotation of the chairmanship, if appropriate.
- Provide for open interaction among panel members and between panel and sponsoring agency.

In this hypothetical example, a list of eight possible impact areas are assumed:

- Recreation
- Noise
- Construction
- Asthetics
- Water quality
- Controlled downstream flow
- Pool fluctuation
- Sedimentation.

A separate card is prepared for each of the above impact subjects. This card includes a brief summary of the nature, effect, source, and so on, of the subject as it relates to environmental impacts of the reservoir under study. The cards are duplicated to provide a deck of eight cards for each participant. Each deck is given a number and the decks are handed out in a random order.

The participants are requested to arrange the cards in their decks and number them in the order in which they perceive the relative importance of the impact of the reservoir, on the topic named, with the most important on top and numbered 1.

Participants are then requested to weight the impacts by assigning a percentage to each impact in relation to the impact on the card above it. Thus the first card would receive a weight of 100 percent. The second might be considered 90 percent as important as the first and be so marked. The third might be considered 95 percent as important as the second, and so on.

The decks are collected and the information is used to calculate the relative importance of the impacts. Before handing in the decks, each participant is asked to make a note of the number of his deck so that it can be returned to him for a second round.

Weighting is accomplished as shown in Table 24 for one deck. Columns (A) and (B) contain the information obtained from the deck. Column (C) shows the conversion to a scale of weights. Since the total of (C) will be different for each deck, the weights are standardized by distributing 1000 points in proportion to the numbers in Column (C) in the manner shown by Column (D). Thus, the totals for each deck will equal 1000.

Table 24

VOTES AND WEIGHTS IN "MINI-DELPHI"

(A) Impacts in Descending Order of Importance	(B) Relative Percentages		(C) Percentage of First Impact	(D) $\frac{1000}{423} = 2.36$ 2.36 × (C)
1. Aesthetics	100%		100%	237
2. Recreation	90		90	214
3. Sedimentation	95	(95% of 90)	86	203
4. Construction	65	(65% of 95)	56	132
5. Controlled downstream flow	80		44	104
6. Water quality	70		31	73
7. Pool fluctuation	40		12	28
8. Noise	30		4	9
Totals			423%	1000

Next, the numbers in Column (D) for all cards are totaled for each impact and the rank order of the impacts is arranged in descending order of those totals. This order then represents the result of the first round.

The results of this first round are presented to the participants and subjected to a period of general discussion. The decks are then returned to the participants for a second round in which the participants may revise their initial rankings and weightings to reflect new insights gained in discussing first-round results.

Finally, the decks as revised are again analyzed as before and the result is taken as the group consensus.

The procedure can also be applied to a variety of other problems, such as ranking the attributes of each plan in a set of alternative plans, as an aid in ranking the alternative plans, or as a means for capturing, or testing the commitment to, a set of policies.

ALTERNATIVE FUTURES

General Description

Abstract

Alternative futures methods of forecasting emphasize what may plausibly happen rather than what is predicted to happen. Study of an array of alternative futures is helpful in setting organizational long-term goals and policies, in charting primary strategies, and in developing contingency plans. It is pointed out that a given potential development may or may not occur; if it occurs, it may happen at any of many different times, and may have any of many different potential impacts. Each unique combination of these and other variables constitutes a different alternative future. Morphological analysis and divergence mapping are discussed as examples of alternative futures methods. The techniques are best adapted to mid- and long-term planning. A major problem is to avoid confusing developments that are reasonable possibilities with those that are expected.

Definitions

Techniques designed to develop alternative futures focus on defining conceivable, possible, plausible, and probable futures. The emphasis is on what societal features could reasonably coexist rather than on how trends will in fact develop. The approach is designed to stretch the mind, surface hidden assumptions, and force systematic consideration of the implications of all varieties of futures, not just those that seem to be without surprises.

A given alternative future consists of any one combination of assumptions about what is conceivable, possible, and probable, together with assumptions about what will or will not occur, when the occurrences will be scheduled, and what the impact of such occurrences will be. It is, in brief, designed to portray a whole, organic society and not just a part. Since each of the dimensions consists of a great many possibilities--and since any combination can differ from all others by no more than a single item--the number of alternative futures is nearly infinite, no matter how narrowly we choose to define the topic of conjecture.

While every forecasting or conjectural project confronts a virtually infinite number of potential futures, only the merest handful can be examined in any detail. It is essential, therefore, to resort to some procedural framework that enables us to select for study those few potential futures that, for whatever reason, strike us as being of greatest interest or value. One such approach to alternative futures is called morphological analysis.

Morphological analysis is at once a generic term and the name of a particular application of the generic approach. In modern times, the approach was developed and advocated by Fritz Zwicky, the late Swiss/Cal. Tech. astronomer. Zwicky--carefully pointing out that the basic approach was in use as early as the 1200s--established the Society for Morphological Research in Pasadena in 1961. A variant of morphological analysis is the so-called FAR (Field Anomaly Relaxation) Method developed and used at the Stanford Research Institute in the late 1960s. A third example of morphological analysis is the Divergence Mapping method devised by two authors (Miller and Schwartz) of the present Handbook in the early 1970s, and now finding increasing use in the corporate sector.

Morphological analysis methodology may be characterized by briefly reviewing Zwicky's approach, which he applied to technology forecasting. First, one makes an exact, definitive, and generalized statement of the problem to be solved, say, propulsive power plants. One then resolves the problems into functional specifications that detail what basic functions must be performed. For instance, a propulsive power plant must store fuel or receive energy from some source, must convert the energy into suitable forms, distribute it somehow to points of traction if it is for surface vehicles, and so on.

For each function, an exhaustive list of possible means of performing the function is compiled. These lists are then combined in a matrix, with each row representing a function and the columns representing alternative means of performing that function. Now, each possible route through the matrix between the first and last rows represents a different potential design for the power plant.

The number of different combinations is very large, since a change in even one row represents a new combination. The analyst then goes through the matrix, assigning efficiency or other preferential weights to every option. These ratings indicate those few combinations that qualify for further study. If too many candidates remain, minimum thresholds can be raised until an acceptable number of candidate solutions remains for final assessment and selection.

Analogous approaches are taken by the FAR and Divergence Mapping methods. FAR and Divergence Mapping, however, to date have been used to select and examine futures states of U.S. society, rather than future technological devices or systems. In Divergence Mapping, for example, 22 different narrative "snapshots" of possible future societies are devised, based on critical issues specified by the user and written in such a fashion that no particular future date is explicitly implied. Users are then required to position these snapshots or frames along a sooner-later line on a blank divergence map form. (This form has 22 slots, hence the need for 22 frames. Maps of any size could be used.) With the frames in place, users then trace alternative future history tracks from the present to the most distant future. Finally, users examine the implications of each future history for the critical issues they had previously identified.

Assumptions

Alternative futures methods are not used unless the user assumes there is real value in exploring what <u>might</u> be in addition to what is <u>predicted</u> to be. More specifically, it is assumed that:

- A forecast or conjecture topic can be defined clearly enough to enable individuals to bring to bear their insights and experiences in inventing alternative futures for the topic.

- Systematic exploration of subjective sketches of the future can make them more quantitative, explicit, and analytic.
- Subjective judgment is a practical, useful way to select a few potential futures for serious study, out of a virtually infinite number of possible futures.
- For many topics and purposes, there exists no substitute for subjective judgment, while for many others subjective judgment is assumed to be as valid as objective judgment.

History

As mentioned earlier, the methodical use of subjective estimates to identify all possible combinations of a system is of ancient vintage, extending back at least as far as the mystic Majorcan monk, Ramon Lull, in the late 1200s. In contemporary times, the development and use of such methods is one of the main themes in the rise of technology forecasting and societal forecasting methods. Loosely speaking, most methods--objective and subjective--now widely known or in use have their origins in work dating from the late 1950s.

Probably because the earliest recent work emphasized the forecasting of physical technology, objective methods were developed and used first. As it became apparent that analyses even of physical technology become conjecture at some level of scope and complexity, attention also turned to subjective methods. This interest quickened in the mid-to-late 1960s, as interest and support built for systematic conjecture about societal phenomena. The absence of strong theories--or even good models--to explain societal change made it mandatory to resort to subjective methods in such cases. While it is difficult to judge, it may be that as of the mid-1970s there is more interest in the development of subjective methods than of objective methods.

Main Uses

Alternative futures methods find their main applications in two categories. In one category are studies concerned with prospects for whole societies. Usually, society is taken to mean some nation-state such as the United States, although some studies deal with global regions (e.g., the Third World) or even with the world as a single whole. In a second category, alternative futures studies reflect the missions or concerns of their sponsors. Even this second category of study, however, more and more often acknowledges and tries to deal with the impact of the large society on particular interests. Examples of this second category would include the Educational Policy Research Centers supported by the U.S. Office of Education, the current worldwide opinion poll of corporate planners (Project Forethought), or the use of divergence mapping as a strategic planning tool by several major corporations.

Limits and Cautions

The principal limit and caution to be observed in alternative futures studies is easily stated but difficult to observe: such forecasts or conjectures are subjective. That is, they reflect the never-wholly-exposed training, experience, attitudes, values, and motives of their participants. The same holds true in objective approaches, of course. One might think that the danger of misunderstanding would be greater in a nominally objective study, because there are the subjective element is denied, ignored, or understated. Yet, in a peculiarly elusive way, subjective studies are more treacherous. For example, the participants in a study usually represent a narrow, selective, and biased sample of a population: corporate planners are much more nearly like each other than they are like other groups in society. Unconsciously, they accept many fundamental assumptions peculiar to their subculture. These common but uncommon assumptions may be discovered in the guise of a consensus forecast about the future. Precisely because the commonality of these assumptions had previously gone unnoticed, a group may accept its collective consensus as a credible, valid forecast of the most probable actual future. In data processing, the term GIGO is widely used: Garbage In, Garbage Out. In future studies, the corresponding term would be AICO: Assumptions In, Conclusions Out.

Other Techniques

Techniques for future studies that are most interchangeable with alternative futures methods are described in other sections of this Handbook. They are scenarios and related methods and expert-opinion methods.

Product or Result

Like all qualitative methods, alternative futures methods run the gamut of scope, formal organizations, rigor, and product. A two-hour session using a blackboard and discussion may be useful but yield no tangible product. A Zwicky-type morphological analysis may yield reams of computer-generated matrices accompanied by many pages of explanation and interpretation. The SRI FAR method yields extensive sets of clusters, each representing a compressed description of a potential future state of some major component of society. Divergence mapping yields 22 frames (miniscenarios) positioned along a sooner-later line, together with a definition of the present, two or more outlines of alternative future histories, and a statement relating each future history to an organization's critical issues.

Level of Detail

Results tend to be broad, holistic, and impressionistic rather than detailed and fully documented.

Communicability of Results

The communicability of alternative futures studies is extremely variable. While everyone makes incessant use of subjective estimates, few people are acquainted with systematic procedures to make such estimates more quantitative, explicit, and analytic. Furthermore, the procedures themselves may often be complicated and, to many forbidding. There is perhaps an unavoidable tradeoff between the communicability and the credibility of results.

If simple, loose procedures are used the results are apt to be widely and easily communicable--but credibility will suffer. If--as in morphological analysis--elaborate, rigorous procedures are used, credibility may be improved (perhaps too much so)--but many people will be unable or unwilling to take the time and effort to understand what has been concluded.

Credibility of Results

The purpose of developing alternative futures is less to devise credible portraits than it is to develop a diverse array of possibilities. Hence credibility is less of an issue in these techniques than in others.

Span of Forecasts

While in principle any future time span can be used in an alternative futures study, in practice the time span is determined by two factors. First, there is the estimate of the minimum interval of time required for significant change in the topic of interest. For instance, one would not in most cases make an alternative futures study of changes in societal trends during the next 12 months, because one would assume that broad trends require significantly longer than that to undergo substantial change. The second factor determining an alternative futures time span is how far into the future participants feel qualified or inclined to render subjective estimates. Clearly, this factor varies greatly from one person, topic, or occasion to another. A safe generality is that alternative futures are excellently adapted to looking long distances ahead, work reasonably well for medium-range forecasts, and usually should yield to other techniques for short-range forecasts.

Resources Needed

Alternative futures studies may be conducted at virtually any level of effort. The resources required vary accordingly. A two-hour blackboard-discussion session requires little more than a trained facilitator and the time of the immediate participants. A divergence mapping exercise may require a few person-weeks of effort extending over a period of two or three months. A morphological analysis or a FAR study may require many person-months or person-years, as well as an extensive data base, experts in many fields, and computer facilities.

Procedures

Planners will have little trouble in performing the more elementary forms of alternative futures studies. For more elaborate forms, instruction will be needed in procedures and in developing a strong data base.

Case Example

Alternative Futures of Inland Waterway Traffic

In 1972 and 1973, the Office of Emergency Preparedness in the Executive Office of the President issued two major reports

that explored possible future energy options for the nation.*
These studies explored two major policy options:

- Depression of energy demand (especially petroleum)
- Substitution of coal for petroleum.

The potential implications of these policies, if implemented, are enormous throughout the economy. From the Corps' perspective, an especially crucial consideration is the impact on volume, origins, and destinations of coal shipped on U.S. inland waterways. At present, one out of every five tons of coal mined in the United States travels on inland waterways. Federal policy innovations involving coal could drastically increase or decrease that figure.

The IWR elected to explore the implications of the two OEP studies with respect to this single issue. OEP's assumptions and data were adopted, supplemented by IWR's other data sources, knowledge, and experience. (For example, IWR made some supplementary assumptions about schedule slippages in construction of nuclear power plants.)

As a departure point, trend data on inland waterways coal shipments were compiled. It was decided to project historic trends into the future on three different bases:

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*Executive Office of the President, Office of Emergency Preparedness, The Potential for Energy Conservation, October 1972; and Substitution for Scarce Fuels, January 1973.

- Alternative I: Extrapolate current trends
- Alternative II: Apply energy conservation measures
- Alternative III: Apply fuel substitution measures.

For many reasons, the potential percentage of all mined coal shipped on inland waterways in the future may vary significantly from past trends in all three of the alternatives chosen for exploration. Realizing as much, a simple, standard range of variations was adopted. This range was projected for all alternatives, enabling direct comparison among the three for each of three different assumptions. The range of variation adopted, based on current trends, was as follows:

- Current percentage of coal shipped via inland waterways 20%
- Current percentage halved 10%
- Current percentage increased by half 30%

At this point, a series of numerical assumptions was made about future trends in factors that would most affect total coal shipments. These assumptions were carefully interlinked in a cross-impact model, so that analysts might vary one assumption and so analyze its impact on the others. The factors so treated included:

- Total coal production
- Demand for energy
- Aggregate price of energy
- Environmental quality
- Crude petroleum imports
- Foreign exchange debits
- GNP.

Summing up to this point: OEP suggested two specific energy policy options, energy conservation and fuel substitution. The study was designed to probe the alternative potential future impacts of these policy options on shipment of coal by inland waterways. Using the historic trend and the fact that 20 percent of all mined coal currently is shipped on inland waterways, seven important factors that would most affect future total coal production were identified. Three basic alternatives were then projected: current trends, conservation measures, and substitution measures. For each of these trends or conditions, IWR explored three variations of percentage of coal shipped via inland waterways: the current percentage (20 percent), increased percentage (30 percent), and a decreased percentage (10 percent).

This procedure yielded nine projections, all within the minimum-maximum envelope indicated in Figure 30. For a full presentation and discussion of the nine alternatives, the reader is referred to the full report.*

The reader should take special care to note that the effort was not intended to be and in fact was not a forecast. The study's point of departure was an OEP staff study that merely suggested two policy alternatives for discussion and deliberation. The study therefore was limited to exploring hypothetical alternative futures in which either or both of the policies were implemented. Such

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*Implications of OEP Energy Conservation and Fuel Substitution Measures on Inland Waterway Traffic, Institute for Water Resources, March 1973, 18 pages.

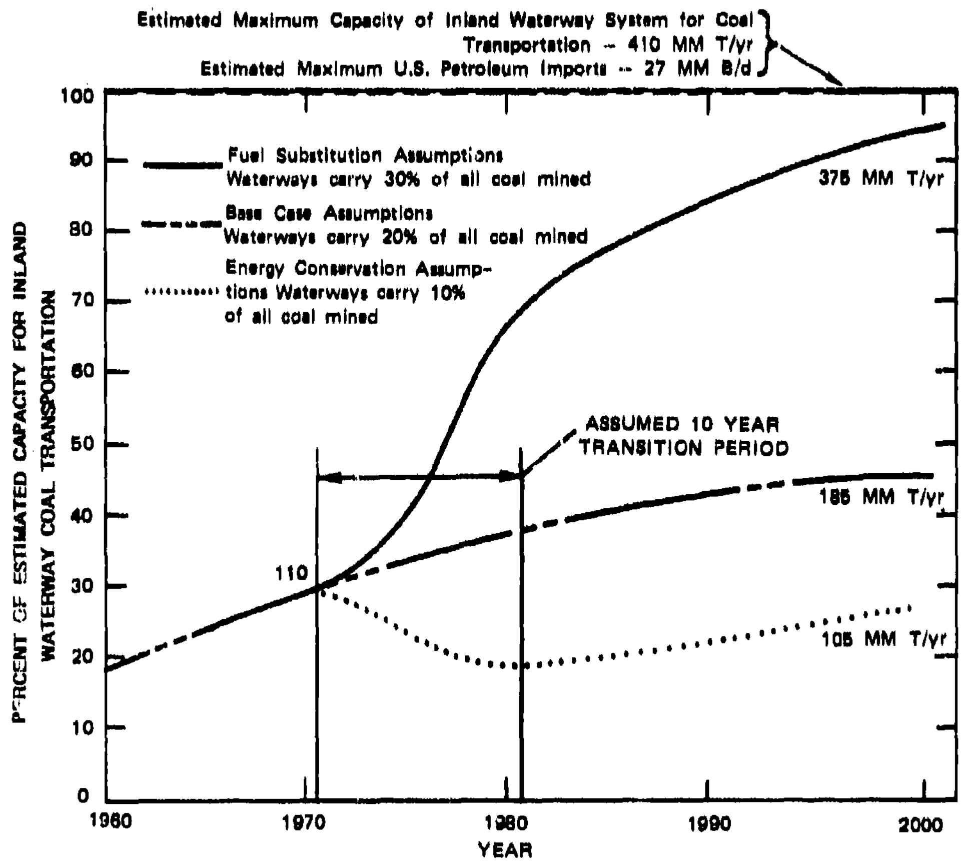

FIGURE 30 ALTERNATIVE INLAND WATERWAY COAL SHIPMENTS

studies are useful not only because they enable the Corps to assess and respond to suggested policies, but also because they clarify and elaborate on interdependencies involved in Corps projects.

VALUES FORECASTING

General Description

Abstract

Of all the techniques for looking ahead, values forecasting perhaps holds the greatest promise while to date it has yielded the fewest practical results. People's values (priorities, opinions, attitudes, and so on) are of crucial importance in judging what public actions and policies they will support. Data on these matters can be collected through survey methods. Forecasts of changing values usually involve clustering values into a typology and forecasting on the basis of demographic shifts or broad societal scenarios. Values forecasting is essential for the purpose of reflecting "soft" human factors in long-term planning and policy analysis. At the present state of the art, values studies are extremely helpful when used in conjunction with other forecasting methods but are of limited reliability or detail when used alone.

Definition

In discussing valuation-based methods of futures forecasting, we arrive at what is indisputably at once the most important, most provocative, potentially most powerful, most primitive, most recent, and most controversial component of the entire futures research field. In the following pages we have attempted to convey a sense of what all the excitement is about.

Why is it that individuals--or families or organizations or peoples or nations--behave as they do behave, rather than otherwise? At the personal level, each of us knows persons whose behavior we characterize as "eccentric"--or "nutty" if we are in a less kind mood. We acknowledge that such persons behave in a characteristic fashion. But what pains us is that their behavior is beyond our understanding. We observe how they behave without understanding why they "act like that." In the absence of any insights into the whys of their behavior, we are unable to predict what they may do in any given situation, and so are constantly--sometimes painfully--surprised by what they do.

Buried inside this frustrating failure to understand each other is a subcultural dilemma. Which persons, groups, or organizations in a society are judged to be odd or deviant is more than anything else determined by who makes the judgment and who has the power to enforce such judgments. One shorthand way to refer to this puzzle--without beginning to explain it--is to refer to value differences between or among individuals, groups, organizations, peoples, and nations. From this perspective, everybody behaves rationally in accord with whatever s/he/they believe to be real and with whatever s/he/they believe to be important in a given case. Thus the primitive bushman who is afraid to have his photograph taken is behaving rationally, once we understand that s/he sincerely believes that her/his soul or spirit can be physically imprisoned in her/his photographic image.

On the face of it, all this seems incredibly distant from the problems facing, say, the developer of a water resources project proposal. And yet the distance is more apparent than actual. Why is it that many proposals are opposed angrily but effectively at the last moment by parties who until that point had evidenced no interest or concern? Surely the explanation must include some consideration of differences in view about what is real and important. Extreme behavior may be explained on the basis that cherished values have been--or are perceived to have been--attacked by others who have no awareness of or concern for the importance of such values. In a fundamental sense, the proposal and execution of projects in the public sector is inescapably political. And politics, in turn, is inherently a matter of mutual accommodation of conflicting values through bargaining and compromise.

Value differences, then--whatever values may be--are a crucial factor in estimating what can and cannot be done. Political activity--partisan or nonpartisan--strives to ameliorate conflicts that can never be resolved. Politicians reach for the immediately acceptable answer. Is there some basis for getting on with this project that all parties can accept, even though no party is fully satisfied? Negotiation, compromise, horse-trading, bargaining--these are the tools of the practical applied values technologist.

Values and the valuation process are difficult-to-impossible to define, measure, or agree upon in making joint decisions--that is, decisions where more than one party has an interest and some power to influence the decision. Small wonder, then, that values analysis is so difficult and treacherous. But the difficulties only begin there. For the fact is that values--whatever they may be--change.

Again at the personal level, the same person may change the values he defends from one situation to another or from one period in his life to another. It is precisely because values and value priorities change that values forecasting methods are of interest. In simpler, more stable cultures than ours value changes may be scarcely noticeable. Even today there are many people who argue that "what was good enough for grandpa is good enough for me." In medieval times, a person born a serf had no aspiration or expectation of becoming lord of the manor. Industrial societies afford a drastically different view of realities and priorities. Technological advance, economic growth, improved access and attainment standards in education--these are only a few of the forces that work for shifts in value priorities. Values forecasting acknowledges the instability of value preferences in modern times. Values forecasting aspires to forecast possible shifts in personal and societal values over time. On the basis of such insights--when they can be achieved--it is possible to foresee shifts in behavior, or what may happen in the r al world. It is for this reason that values forecasting is important, and also why it is so difficult. Next we consider briefly some approaches to values forecasting.

Over the centuries many writers have propounded theories about societies--how they got to be as they are, how they are at any given time, and the conditions under which they change to become something different. Often change was imputed to changing values, as in the works of Spengler, Gibbon, Jefferson, and, more recently, Toynbee and Sorokin.

In the past 30 to 40 years, and especially since the rise of psychology as a science, many outstanding thinkers have concerned themselves with types of people, developmental patterns, and a variety of values-based typologies. They were interested in such matters as a means of explaining why people act as they do. Students of social change have employed many of the concepts developed in psychology to explain why men rebel and how societies grow.

Values forecasting has been based on a variety of approaches. Some significant work has been based on changes in a single cultural variable, such as McClelland's work with the drive for achievement. More work has sought to define people in terms of some limited set of values, such as the well-known "study of values" launched in the 1930s by Allport and Lindzey. Still others employ value typologies. Maslow's hierarchy of human needs may be the best known, but it is by no means the only one. Recent work has sought to characterize people in terms of paradigms and ways of life. Life style research and psychographic studies have been developed chiefly in the marketing research field.

The central aspect of all these studies is values and their associated attributes. These attributes include such "inner" characteristics as preferences, desires, beliefs, goals, motives, needs, intentions, opinions, attitudes, and the like. From the pragmatic standpoint, all these "values" are important because they are presumed to influence the individual's behavior and activities. Indeed, there are some who think that the driving force behind the societal change in the United States has recently shifted from advances in technology to changes in values.

Assumptions

Values forecasting depends on a variety of assumptions. First, there is the assumption that people know what they value and what their values are and will honestly report on their feelings when asked in suitable fashion. It is further assumed that people's values shape their priorities and hence their actions. Conversely, the technique assumes that exterior conditions affect inner values, so that adverse conditions can be expected to give rise to values, priorities, and actions aimed at remedying the adverse situation. Thus, the most basic assumption in values forecasting is the sequence linking (in either direction) what people care about, what they do, and the kind of future they create. To the extent, then, that the future is unaffected by the desires of men, values forecasting fails short. Because what we want and what we get are so often far removed from each other, values forecasting is considered to be more appropriately used as an input to the total forecasting effort than as a technique to be applied as the sole source of the forecast.

History

Historically, a brilliant example of values forecasting is Alexis de Tocqueville's *Democracy in America*, published in 1835. More recently, Harvard psychologist David McClelland's study of *The Achieving Society* (1967) is another example. In marketing, perhaps the best-known example is the AIO (Activities, Interests, and Opinions) method developed at the University of Chicago in the late 1960s by William Wells and Douglas Tigert.

Extensive work in the field is going on at the Survey Research Center at the University of Michigan, at Stanford Research Institute, and at several corporations and universities. The field is still very much in the formative stage.

Main Uses

Values forecasting is in a state of rapid evolution. Its main uses to date have been in the fields of voter and consumer opinions and behavior. More recently, a broader, longer-run emphasis has begun to emerge. For example, major projects in the states of Washington, Iowa, and Massachusetts have been undertaken to determine citizen preferences for future growth and development priorities. Consumer groups, public interest advocates, and public and private groups interested in environmental issues are seeking to establish general preferences (as well as their own legitimacy) in a variety of survey research activities. Values forecasting is also finding a growing role in broad societal forecasting, in institutional long-range planning, and in much policy analysis. Many studies of quality of life place values at the core of analyses.

Limits and Cautions

Values forecasting techniques are ambitious in their aspirations but woefully weak in demonstrable validity. They are uniquely useful in incorporating the "soft" elements of a society into a forecasting project--such matters as motivations, beliefs, and preferences. It is abundantly clear that projections that ignore these issues are inadequate and deceptive. It is also clear that our ability to deal with such components in examining societal prospects is limited.

There is a fundamental and unresolved disagreement among authorities as to how much difference value priorities actually make in the behavior of individuals and subpopulations. In supporting or opposing a flood ontrol project, for example, some observers argue that values and principles weigh heavily in determining positions. Others contend that immediate self-interest (what's in it for me?) is nearly always the major determining factor. Still other experts would hold that immediate, incidental or accidental forces heavily determine the shape and views of a stakeholder population.

In any case, most exp(rts agree that value differences are complex and subtle, and that changes in value position occur so obscurely as to be difficult to account for or predict in many instances. Most authorities would also agree that values studies insights are necessarily global in nature, and may be difficult to relate to detailed, specific concerns or proposals.

Given both the increasing recognition of the importance of values forecasting and of its severe limits, wisdom and caution in using such methods and in relying on their outcomes is indicated. The soundest counsel is not especially helpful: one should always try to incorporate such components in a forecasting effort; yet one should never rely on such methods exclusively.

Other Techniques

The other forecasting techniques that are most interchangeable with values forecasting methods are policy capture, scenario writing, alternative future techniques, and some of the expert-opinion methods, notably surveys of opinions and attitudes.

Product or Result

The typical product of a values forecasting effort is a document in which the values, priorities, and opinion of the population studies are defined and often sorted into a small number of subtypes. Typologies may be based on the life-cycle (couples with young children, retired couples), around life styles ("swingers," "contented cows"), or some other dominant trait of interest to the study sponsors. Forecasts of anticipated shifts in the "profile" of value clusters are often provided. The study report will also typically include correlation analysis among the items reported or observed. Finally, an interpretive section will be provided, attempting to make significant and useful generalizations and predictions about the behavior (through time) of the population sampled.

Level of Detail

Values forecast studies are almost always more global and less detailed than those typically provided by other methods. Even compared with other qualitative forecasting methods, values forecasts tend to be general.

Level of Confidence

As noted above under "Limits and Cautions," sponsors of values forecast projects should regard the results with care. Value studies are useful for raising significant possibilities that might otherwise be missed and for enriching forecasts produced by other means.

Communicability of Results

Concepts, models, and theories about opinions, attitudes, beliefs, and values are still in the most primitive stages of development. As a corollary, these topics at best are extremely difficult to discuss or debate in a useful way. Within this framework, values forecasting projects do a great deal to clarify and convey agreements and disagreements about critical issues, variables, and results.

Credibility of Results

Values forecasting projects are easy and favorite targets of their critics, who are numerous. In the first place, many people ideologically refuse to believe that any characteristic that cannot be rigorously counted or measured can be significant. In the second place, the primitive state of value-change theory invites mockery and ridicule. Further, most people have strong preconceived notions on most subjects and tend to insist on their models, rather than explain them. Because values forecasts are inherently vulnerable to criticisms from any quarter, and are also favorite targets of sarcasm, they can be useful in identifying critics and understanding the nature of their ideological views.

Span of Forecasts

The time span of values forecasts is heavily determined by the particular dimension of interest. In presidential opinion polls, the time span is set by the date of the next presidential election. Many consumer marketing research studies emphasize the next three to twelve months. Where fundamental values and value changes are the primary interest, time spans of several years to many decades must be taken into account.

Resources Needed

Values forecasting is an expensive and time-consuming business. Even if an existing values typology is adopted, considerable expense is involved in developing and administering a survey instrument for the particular subject under study. Processing and analyzing findings can also be costly. Specialists in values, survey research, and statistics are required for this work.

Value forecasts (as distinct from data collection and patterning) usually are tied to forecastable characteristics of the population under study (age, life cycle, occupation, income) that correlate highly with specific values and values patterns or to broad concepts of societal evolution. The first approach is straightforward and easy; the second requires much judgment. In most cases, both should be carried out and cross-checked--another reason why values forecasting is expensive.

Procedures

The business of forecasting value change is still far more of an art than a science. The planner seeking the best advice and insight will ask aid of experts in attitudinal measurement, societal change, personality development, history, religion, and perhaps others. Such consultants can provide frameworks and results of past values studies, but none of them can claim to offer a forecasting method of high objective reliability. Given this state of affairs, the planner perhaps should start with her/his own set of intuitive values forecasts. These plausible alternatives can then be refined and perhaps changed in number in the light of systematic critiques by the publics involved in the decision at hand and by the kinds of experts mentioned above.

Two illustrations of values research are given below. The first is a purely hypothetical example describing a method of forecasting changes in values; the second deals with an actual project the aim of which was to assess value priorities.

Case Example

A Hypothetical Susquehanna Life-Ways Study

For many decades it was sufficient to assess water resource project proposals in terms of a few conventional, relatively clear-cut goals, such as flood control, adequate water supplies, and satisfactory inland waterways.

In recent years, however, other, less clear-cut requirements have demanded attention and consideration. Among these, one of the most troublesome for planners has been future demand for recreation use of water resource lands and facilities. Rising affluence, increasing leisure time, greater mobility, loss of much open space to housing and industrial development, demographic changes--these are a few among many trends that have made recreational land-use problems at once much more important and much more complex than in former years.

Acknowledging this challenge, the IWR (hypothetically) determined to engage in basic, exploratory research in the field. IWR became convinced that mere projections of past trends in a region--or even use of a model formula in one area that had been used with success in others--was an inadequate approach to the recreation challenge. IWR suspected that more fundamental changes--changes in people's life styles--had become and in future would be ever more important determinants of recreational behavior. Accordingly, IWR sought to discover and to make an exploratory research application of some social-behavioral model that sought to address such factors.

Having reviewed the field, IWR selected the "life-ways" model as a suitable vehicle for exploratory research in the field. In due course, a work plan was developed and a study contract negotiated with a qualified contract research organization. IWR quickly discovered that such basic research is not simple or inexpensive. The (hypothetical) contract entailed many man-years of effort over a period of 30 months. While a project of this scope cannot be discussed in detail here, the main features of the study are briefly outlined in the following paragraphs.

The life-ways approach argues that by combining several observable and evaluable characteristics, individuals in an adult population can be assigned to one among a half-dozen basic life-ways types. (The model acknowledges that such a typology is grossly oversimplified, and that even 60 life-ways types could not exhaust the varieties of human behavior observable in any community. Nonetheless, the model argues, it is useful to begin with a very few basic types, then extend the typology, as experience and the requirements of particular studies dictate.) The six basic life ways called out in the model are:

- Makers--These are the men and women who, working effectively within the system, make it go.
- Preservers--Persons with this life way, at ease chiefly with the familiar and proud of tradition, act as a sea anchor on change.
- Takers--Takers coast. Making as few waves as possible, they take what they can from the system, feeling little obligation to the hand that feeds them.

- Changers--They tend to be answer-havers; they commonly wish to change things to conform with their views.

- Seekers--These are the people who search, often gropingly, for a better grasp, a deeper understanding, a richer experience, a universal view.

- Escapers--They are the lotus eaters. Their chief life drive is to escape, to get away from it all, to shun the pressures and demands of everyday life.

Without going into details, the life-ways model argues that most contemporary Americans fall into the Maker and Preserver categories. However, the model holds, difficult and rapidly changing times such as our own induce small but significant shifts into the other life-ways categories. If we can discover (crudely estimate) how many people in a population fall into each category, and if we can determine which categories are growing in a population, then we can anticipate value shifts. The model also emphasizes that life ways are not to be confused with life styles. A life way represents a cluster of inner motivating values, while a life style represents any among many, many different behavior patterns through which the driving value cluster can be expressed. Thus, there are many potential life styles for each and every life way.

In the IWR exploratory research project, the object was to determine if the life-ways model could be intelligibly applied to an actual population. The region selected was the Susquehanna River Basin, comprised of specified counties in New York, Pennsylvania, and Maryland. It was hoped that survey research methods might make it feasible to estimate crudely what fraction of the adult population in the study region fell into each of the life-ways categories. It was also hoped that emergent trends in changing life ways might be identified. If this could be done, IWR felt, useful new insights valuable for recreational and many other water resources planning purposes might be obtained. However, the frankly exploratory nature of the work was emphasized, so that advance guarantees of immediately and directly usable results could not be given.

But how was the actual sorting of people into life-ways categories to be accomplished? The life-ways model itself offers a key to the allocation task. The model argues that each life way is associated with distinctive patterns under each of the following main headings:

- Life goals
- Sources of meaning
- Sources of truth
- Psychological needs
- Belief systems
- Morality patterns
- Time orientation.

Under each of these main headings, a standard inventory of items has been devised, representing the range of preferences associated with the various life ways. The number of items under each main heading varies from as few as three under time orientation (past, present, future) to as many as 20 under life goals.

By asking individuals to select preferences under each of these main headings, it was hoped that individuals could be readily assigned to one of the six life-ways categories.

As already mentioned, the survey research approach was selected as the obvious one for the study. Survey research methodology has been well developed for marketing research and is used throughout the behavioral and social sciences as well. Accordingly, a stratified random sample of 1500 adult residents in the region was selected, forming a representative cross section of the population. Experienced field interviewers were recruited and trained for the survey. A structured, face-to-face in-depth interview instrument was developed, consisting of more than 200 items requiring an average of three hours to complete.

Many of the items on the interview form dealt directly with the traits associated with life ways, as discussed above. Other items covered included:

- Standard demographic information (age, sex, years of residence in the region, income level, education level, and so on).
- Items used in earlier values surveys elsewhere, so that results obtained in the Susquehanna Basin could be assessed against other results.
- An inventory of individual pursuits, including associated activities and plans and expectations for the future related to these pursuits.

In barest outline, such was the study design adopted for the hypothetical life-ways forecast study in the Susquehanna River Basin. The project is costly, ambitious, and experimental. Yet the cost and risk are judged by IWR to be commensurate with the growing importance of personal and social values and value changes in every public-sector project.

Again, the reader is reminded that the project outlined above is a hypothetical one, one that IWR has neither scheduled nor contemplated. The scenario is offered here as indicative of the form, dimension, and potential utility of values forecasting projects. It is expected that such studies will become increasingly common in the years just ahead, in both the public and private sectors of society.

Actual Values Study in the Susquehanna River Basin

The Susquehanna River Basin was named as the site of the hypothetical life-ways forecasting study only because of an example of an actual, values-related study project there is available to cite as a second, actual example of values analysis.

In the actual example, the object was to discern how various interested parties in the Basin perceived water resource problem priorities. Although not specifically a forecasting study, it was designed to guide the Corps' future actions. It will be noted that the study partakes both of survey techniques and policy capture but is unique in that it specifically contrasted the values of the research group (the Coordinating Committee) with that of the affected public.

The Susquehanna River Basin Coordinating Committee was organized in 1963. Its mission is to ensure that the three states (New York, Pennsylvania, Maryland) and seven federal agencies (the Corps, Agriculture, Commerce, FPC, HEW, HUD, Interior) have their views adequately represented in the overall planning effort.

In pursuit of its mission, the Committee retained a research team from the University of Michigan. The team was asked to study means of improving communications among the several stakeholders represented on the Committee, and between them and the residents of the Basin.

The particular study cited below was limited to four counties in southern New York State (Chemung, Steuben, Tioga, Broome), and one county (Tioga) in north-central Pennsylvania. In form, the study consisted of a series of face-to-face interviews, plus questionnaires to be completed and returned after the interviews. Persons interviewed were government, civic, and community leaders who either were interested in water resource development or were in any case in a position to influence such development in the Basin. In all, 189 persons were interviewed, of whom 155 completed and returned post-interview questionnaires.

Several issues were addressed in the study, of which only one is discussed here. A list of water resources problems was presented to the interviewees, and they were asked, How would you rank in importance each of these current water resource problems?

Included among the problems listed were:

- Flood control
- Preservation of environmental quality
- Recreation
- Water pollution
- Water supply
- Low-flow augmentation.

Table 25 indicates which four problems were ranked of greatest importance--in which order--by interviewees in each of the counties surveyed.

Separately, Committee members and staff were also asked to rank-order the problems. Actually, they were requested to rank-order the list in each of two ways:

- According to their own personal estimates.
- According to the rank-ordering they expected interviewees in the counties surveyed would assign.

Table 26 tabulates the results of the Committee-staff exercise. Also shown for comparison are the actual rank-orderings assigned by interviewees in two of the counties surveyed.

If for the moment we assume that rank-ordering of problems reflects in part a rank-ordering of values held, it is clear that there were significant value differences between the Committee and its staff on the one hand and residents of the region on the other. It is also clear that--until the survey was made--these value differences were unsuspected by the Committee and its staff.

Table 25

PRIORITY WATER PROBLEMS BY COUNTY OF RESPONDENTS
(Based on total ranking score for each problem category)

Origin of Respondents	First Priority	Second Priority	Third Priority	Fourth Priority
Western Counties				
Chemung Co., N.Y.	Pollution	Water supply	Recreation and flood control	Low-flow augmentation
Steuben Co., N.Y.	Pollution	Water supply	Recreation	Environmental quality
Tioga Co., Pa.	Pollution	Water supply	Recreation	Flood control and mine acid pollution
Eastern Counties				
Broome Co., N.Y.	Pollution	Recreation	Water supply	Environmental quality
Tioga Co., N.Y.	Pollution	Recreation	Flood control	Water supply

Table 26

DIFFERENCES IN PERCEPTIONS OF PRIORITY
WATER PROBLEM CATEGORIES

Sources and Basis of Rankings	First Priority	Second Priority	Third Priority
Coordinating committee (own evaluation)	Flood control	Water supply	Pollution
Coordinating committee (what local people would think)	Water supply	Flood control	Pollution
Local residents of Broome and Tioga Counties	Pollution	Recreation	Water supply

Exactly which values are involved, and why and how greatly they differ, and what they import for project planning--all these pressing issues would require further research for resolution. Nonetheless, as this actual example demonstrates, value differences are important in planning for the future, and they can be uncovered by intelligent use of straightforward methods.

Section VI

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REFERENCES

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Appendix A

FORECASTING TECHNIQUES EXAMINED

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FORECASTING TECHNIQUES EXAMINED

Part I: Initial List of 150 Forecasting Approaches

1. Forecasting via Surveys

    Delphi
    Panels
    Public opinion polls
    Surveys of activities, events, units, etc.
    Surveys of intentions
    Surveys of attitudes and priorities
    Surveys of hopes and fears

2. Barometric or Indicator Forecasting

    Economic indicators
    Social indicators
    Precursor events
    Diffusion indices
    Amplitude-adjusted indices
    Analysis of critical factors
    Signals of change
    Technological audits
    Interpretation of behavior(s)
    Analysis of limits and barriers
    Prediction of changeover points

3. Forecasting via Trends

    Trend extrapolation
    Exponential trends
    Nonexponential trends
    Exponential smoothing
    Time-series data

3. Forecasting via Trends (Continued)

Trends with a limit
Nonlinear trends
Regression analysis
Least squares method
Curve fitting with judgmental modification
Lagged variables
Dummy variables
Statistical probabilities
Probabilistic forecasting
Intuitive extrapolation
Bayesian models
Propagation of variance
Link-relative prediction
Substitution forecasting
Pearl formula
Gomperz law
Envelope curves
Learning curves
Correlation analysis
Correlation coefficients
Autocorrelation
Cycle analysis
Moving averages
Box-Jenkins
X-11

4. Forecasting via Models and Simulations

Growth curve models
Structural models
Readiness models
Rigid (computer) models
Macroeconomic models
Microeconomic models
Statistical models
Diffusion models
Gaming
Gaming theory
Chains of industries

4. <u>Forecasting via Models and Simulations</u> (Continued)

Input-output analysis
Contextual mapping
Cross-impact analysis
Operations research
Linear programming
Dynamic programming
Mission networks
Systems analysis
Functional analysis
Integrated information systems
Logical-analytic frameworks
Adaptive search
Work flows
Parametric sensitivity
Marginal analysis
Risk assessment
Cost-benefit analysis
Feedback techniques
Sensitivity analysis
Utility profiles
Monte Carlo
PERT/time
PERT/cost
Critical path method
Line-of-balance
Milestone system
Gantt bar charts
KSIM
Return on investment
Return on assets
Return on equity
Attribute listing
Technological progress functions
Technological mapping
Perspective trees
Normex forecasting
SRI Gulf energy model
Fuzzy algorithms
Oil price simulation model

4. Forecasting via Models and Simulation (Continued)

Policy capture
Signed digraphs

5. Normative Forecasting

Vertical relevance trees
Horizontal relevance trees
Vertical decision matrices
Horizontal decision matrices
Decision theory
Morphological modeling
Field anomaly relaxation method
Divergence mapping
Qualitative scenarios
Quantitative scenarios
Surprise-free projections
Canonical trend variation
Study of alternative futures
Subjective estimates of probabilities
Estimates of preferences
Social trend analysis
Estimates of needs and priorities
Technological assessments
Policy forecasting
Value analysis
Life styles
Life ways
Policy issue knowledge
Introspective forecasting
Activities, interests, opinions (AIO)
Psychographics
Cross-cultural comparisons

6. Forecasting via Analogy and Creativity Techniques

Historical analogy
Growth analogies
Bionics
Personal analogy

6. Forecasting via Analogy and Creativity Techniques (Continued)

Direct analogy
Symbolic analogy
Fantasy analogy
Hypothetical situations
Brainstorming
"Buzz" groups
"Genius" forecasting
Prescience, clairvoyance
Operational creativity
Analogy with case examples
Utopias and dystopias
Science fiction
Synectics
Study of unanticipated events
Macrohistorical cycles
Thinking in parallel planes
Thinking with specified concepts
Thinking with basic elements
Thinking with outline strategies
Thinking with diverse viewpoints

Part II: The 73 Methods Briefly Described

1. Cost-benefit analysis
2. Statistical models (Bayesian)
3. Marginal analysis
4. KSIM
5. Mission flow diagrams
6. Parameter analysis
7. Cross-impact analysis
8. Input-output analysis
9. World oil price simulation
10. Breakthroughs
11. Precursor events
12. Econometric forecasting
13. Dynamic models
14. Structural models

15. Decision analysis
16. Morphological modeling
17. Decision matrices
18. Relevance trees
19. Theoretical limits and barriers
20. Analysis of industrial behavior
21. Technological audit
22. Social trend analysis
23. Scenario writing
24. Canonical trend variation
25. Surprise-free projections
26. Social indicators
27. Leading indicators (economic)
28. Change signals monitoring
29. Critical factors analysis
30. Estimates of preferences
31. Subjective estimates of probability
32. Prediction of changeover points
33. Amplitude-adjusted index
34. Diffusion index
35. Authority or "genius" forecasting
36. Surveys of intentions or attitudes
37. Surveys of activities or units
38. Panels
39. Delphi
40. Psychographics or life style
41. Activities, interests, opinions
42. Life ways
43. Historical analogy
44. Alternative futures (FAR)
45. Divergence mapping
46. Introspective forecasting
47. Utopias/dystopias
48. Modes and mechanisms of change
49. Study of forces of change
50. Macrohistorical cycle
51. Cross-cultural comparisons
52. Synectics
53. Brainstorming
54. Bionics
55. Science fiction as forecasts

56. Exponential smoothing
57. Simple regression
58. Moving averages
59. Multiple regression
60. Envelope curves
61. Growth curves
62. Link-relative prediction
63. Box-Jenkins
64. Cycle analysis
65. Systems analysis
66. Risk analysis simulation
67. Contextual mapping
68. SRI Gulf energy models
69. Games
70. Policy capture
71. Probabilistic forecasting
72. Normex forecasting
73. Substitution forecasting

Part III: The 31 Methods Described in Detail

1. Trend extrapolation
2. Social trend analysis
3. Precursor events
4. Modes and mechanisms of change
5. Box-Jenkins
6. Probabilistic forecasting
7. Subjective estimates of probability
8. Environmental systems analysis
9. Dynamic models
10. Cross-impact analysis
11. KSIM
12. Input-output analysis
13. Decision analysis
14. Relevanc trees
15. Normex forecasting
16. Policy capture
17. Games
18. Contextual mapping
19. Risk analysis

20. Mission flow diagrams
21. Scenarios and related methods
22. Surprise-free projections
23. Morphological analysis
24. Alternative futures
25. Divergence mapping
26. Authority forecasting
27. Surveys of attitudes
28. Panels
29. Delphi
30. Life ways
31. Synectics

<u>Part IV: The 12 Methods Selected for the Handbook</u>

1. Trend extrapolation
2. Pattern identification
3. Probabilistic forecasting
4. Dynamic models
5. Cross-impact analysis
6. KSIM
7. Input-output analysis
8. Policy capture
9. Scenarios and related methods
10. Expert-opinion methods
11. Alternative futures
12. Values forecasting

Appendix B

GLOSSARY OF TERMS

Appendix B

GLOSSARY OF TERMS

Algorithm: Any system of counting or computing.

Alternative Futures: Combinations of assumptions about what may occur, what will occur, and what the impact of such occurrences will be. Designed to portray whole organic societies.

Analysis: Separating the whole into its parts to discover their natures, functions, and relationships.

Analytical Reasoning: Drawing conclusions by means of analysis.

Attitude: Disposition, opinion, or emotion.

Attitudinal Survey: An opinion poll to obtain data on the attitudes of a population.

Authority Forecasting: Pronouncements concerning the future made by a recognized expert or authority.

Autocorrelation: The degree of correspondence or agreement among values of the same variable at different time periods.

Autoregressive: A model used in the Box-Jenkins method in which the variables are the lagged variables of the initial variable.

Base-Line Forecast: The starting, usually simplistically derived forecast that is refined by more sophisticated methods.

Box-Jenkins: A pattern recognition forecasting technique used where there is no readily apparent pattern to a series of data.

Brainstorming: The unrestrained offering of ideas or possible alternatives in an attempt to reach some creative solution.

Canonical Variations: In forecasting, the different plausible directions in which the present may develop.

Cause-Effect Reasoning: Drawing conclusions based on the premise that whatever occurs is the outcome of some preceding occurrence or state of affairs.

Change-Over Point: The point at which a step function or phase change occurs, signifying a discontinuity.

Citizen Participation: The inclusion of members of affected populations in the planning and/or implementation of a project.

Clusters: Well-defined groups whose members are interrelated and have some commonality.

Conceivability: Within the realm of imagination.

Conjecture: Inference, theory, or prediction based on guesswork.

Consequences: Results of decisions or actions.

Correlation/Correlation Coefficients: The degree of relative correspondence or agreement between two events, sets of data, or theories.

Correlation Analysis: Analytical procedures to derive correlation.

Credibility: The degree to which results are accepted as indicative of reality.

Cross-Correlation: The degree of correlation among variables; more roughly, the impact of one event upon another in a cross-impact matrix.

Cross-Impact Analysis: A systematic means of studying interrelationships among events or developments, often in the form of a matrix in which paired elements are compared.

Cycle: A period of time in which a round of regularly recurring events is completed.

Cyclic Curves: A line on a graph that curves in such a manner as to display a cycle.

Data: Facts or figures, known or assumed.

Decay Curves: A line on a graph that is curved in such a way as to display decreasing values.

Decision Analysis: A probabilistic forecasting method that builds a "decision tree" as a logical approach to a complex, dynamic, and uncertain situation.

Decision Variables: The variables to be taken into account in building the decision tree.

Delphi Polling: A special type of opinion polling technique in which participants may compare and revise estimates before a final conclusion is reached.

Demographic: Relating to population studies--birch rates, age spectra, places of residence, and so on.

Discontinuity: A sudden change in a trend that is not explained by historical data.

Divergence Mapping: A type of futures exercise in which "snapshots" of possible future societies are fitted into a blank form along a sooner-later line. The map is then used to trace alternative future history tracks.

Dynamic Model: A formal model that allows changes in the system to be derived as a function of time.

DYNAMO: A computer-language compiler designed for computer simulation of dynamic models.

Envelope Curves: Curves on a graph that form an envelope or outer limits for the phenomena of interest.

Environment: The conditions, circumstances, and influences that surround and affect an individual, group, place, or thing.

Event Path: One of a number of possible tracks along the branches of an event tree.

Event Tree: An approach used in risk analysis to estimate the failure probability of various protective components.

Expert/Expertise: Recognized as having much training or knowledge in a particular field, and hence considered to be expert.

Explicit Assumptions: Those things overtly expressed that are taken for granted.

Exponential Curves: Lines on a graph that display the character of exponential growth. Also called "J" curves in reference to their appearance.

Exponential Smoothing: The procedure of fitting data of exponential form to a smooth curve.

Extrapolation: Extension of data over time according to specific rules.

FAR: Field anomaly relaxation; a term used to describe one kind of morphological analysis used to devise scenarios.

Fault Tree: An approach used in risk analysis to determine the probabilities and consequences of impacts resulting from a fault in the system.

Feedback: The return of part of the result of an event to affect the event itself.

Feedback Loop: A line in a dynamic model that traces the cause-and-effect relationships from a given variable back to itself. May be positive (additive) or negative (subtractive).

Field Anomaly Relaxation: See FAR.

Forecast, Forecasting: Used in several senses: prediction, identification of possibilities, physical plausibilities, desirables; is usually to be distinguished from a projection.

Frames: The "snapshots" used in divergence mapping to outline or portray one possible future at one point in time.

Frequency Distribution: An arrangement of data that shows the frequency of occurrence of the different values.

Future: The prospective or potential conditions of a specific group, place, event, institution, in a time that is to come.

Futurism: The art and science of studying the future.

Futurist: One who engages in studies of the future.

Goal: The object or end that one strives to attain.

Growth Curve: A line on a graph that displays the manner in which something grows.

Histogram: A bar graph showing the frequencies of occurrences of a specified item within a specific range.

Holistic: As a whole; all at once; including as many aspects as conceivable; the totality.

Impact: Force or effect of one event on another.

Impact Assessment: A determination of the nature and relative importance of the effect of one event on another.

Implicit Assumptions: Those things, understood though not overtly expressed, that are taken for granted.

Indicator: An event or situation that may be taken to express, or indicate, the presence of an event or situation in a different area; proxy data.

Inflection Point: The point at which a curve changes its rate or direction of change.

Input-Output Analysis: A descriptive model of the economy in which I-O tables are used to trace, predict, or evaluate the effect of changes in the system.

Input-Output Tables: These tables show the physical relationships (such as value, flow) among goods and services in an industry, region, or some other entity at a specified point in time.

Intentions Survey: Surveys of the intentions of people regarding some future act they might take.

Interactive Computer Models: Models that are designed so that the user may alter interacting variables in the program and have the computer simulate the model's behavior under new conditions.

Interquartile Range: The value below the median that encompasses one-quarter of the data and the value above the median that encompasses a second one-quarter of the data.

Intervening Variable: The link between two events; the intervening variables of most interest in forecasting work are causal variables and correlating variables and (what are often mistaken for these) coincidental variables.

Intuitive Reasoning: Drawing conclusions based on intuition.

Inventory Theory: A framework of concepts and procedures by which probabilistic estimates of given needs and times can be made.

<u>KSIM</u>: A cross-impact simulation technique that uses both quantitative and qualitative data in a computer program that calculates and displays changes in variables over time. KSIM stands for Kane SIMulation, after Julius Kane, inventor of the method.

<u>Lagging Indicator</u>: An event or situation that may be taken to express, or indicate, the earlier occurrence of an event or situation in a different area; opposite of a leading indicator.

<u>Leading Indicator</u>: An event or situation that may be taken to express, or indicate, the probable later occurrence of an event or situation in a different area; opposite of lagging indicator.

<u>Life Style</u>: The manner in which an individual outwardly expresses his/her existence; distinguished from life way in being more superficial, changeable, and exterior.

<u>Life Way</u>: A basic personality type characterized by clusters of motivating values; to be distinguished from life style (which see).

<u>Linear Curve</u>: A line on a graph displaying the results of an equation whose variables are in the first power only (i.e., non-exponential).

<u>Long-Range</u>: Far off, distant, not immediate; in forecasting, usually refers to five years or more into the future.

<u>Markov Process</u>: A probabilistic forecasting method from which is estimated the probability that a process will be in a given state in an event chain.

<u>Mean</u>: Arithmetic average; found by dividing the sum of two or more quantities by the number of those quantities.

<u>Mechanism of Change</u>: The means or instrument by which a change is brought about.

Methodology: A system, or orderly arrangement, of methods.

Model: A representation or simulation of a system or process showing interacting elements.

Modes of Change: How or why a change occurs.

Monte Carlo Simulation: A process analogous to roulette in which combinations are thrown out at random. Estimations of probabilities are made from records of these combinations and used for forecasting.

Morphological Analysis: The process of resolving a basic problem area into its basic elements, then combining and recombining these elements into new arrangements for further study. See also divergence mapping and FAR.

Morphology: The scientific study of form and structure.

Moving Average: A model used in the Box-Jenkins method that subtracts previous values of the error from the residual. It is also a means of smoothing data in making trend extrapolations.

Multiple Regression Analysis: The numeric procedure of calculating the coefficients among more than two series of variables.

Non-Markov Process: A probabilistic forecasting method in which is estimated the probability that a given event will occur following another given event dependent on previous such transition probabilities.

Normative: Pertaining to preferences, goals, norms.

Normative Future: A future expressed in terms of goals and preferences rather than in terms of predictions or probabilities.

Normex: A forecasting method that combines normative consideration with trend extrapolations.

Objective: Determined by the characteristics of the subject rather than by preferences or emotions; without bias or prejudice insofar as possible; value-free. Often contrasted with subjective.

Operations Research: An early form of systems analysis developed in the military during World War II.

Opinion Polling: A survey research technique in which a selected group of participants are asked their opinions on a specific topic.

Optimization: Probabilistic methods in which are compared every alternative with a desired outcome in order to secure the most desired results with the fewest undesirable consequences.

Panel: A selected, organized group of experts.

Paradigm: A pattern or model.

Parametric Sensitivity Analysis (PSA): A probabilistic forecasting method in which is estimated the relative importance of each input into a situation.

Pattern: Arrangement of form; disposition of parts or elements; tendency or characteristics.

Pattern Analysis: Separation of the pattern into its elements to discover functions and relationships.

Pattern Identification: Forecasting based on the recognition of a pattern in time-series data or trends. Used where data are fuzzy or too complex for more direct methods.

Planning: "Intelligent cooperation with the inevitable."

Point and Interval Estimation: A method of calculating the probabilities of various outcomes of a specified event.

Poisson Distribution: Refers to the random distribution of arrivals in a given period of time (i.e., no special pattern).

Policy Capture: The construction of a mathematical description of an individual's priorities in order to under his/her judgments (i.e., policies) and predict future judgments.

Possibility: Something that may or may nôt happen; to be distinguished from probability.

Potential Future: A description of what can be in a time to come; to be distinguished from a forecasted or predicted future.

Precursor: A forerunner, harbinger, or leading indicator.

Prediction: A statement of what will be; to be distinguished from projection, probability, and possibility; often used synonymously with forecast.

Probabilistic Forecasting: The use of mathematical models to predict the future behavior of phenomena that behave in a random manner.

Probabilistic Matrix: A table with values showing probability distributions.

Probability: The quantified likelihood of something occurring in a given way at a given time.

Problem: A question proposed for consideration; an issue, difficulty.

Problem Assessment: Definition of the implications of a question or issue.

Problem Identification: The definition and limiting of scope of the alternatives and impacts to be considered relative to the original question or issue.

Projection: A statement of what may be, based on analysis of what has been and is; distinguished from prediction, forecast, and probability.

Proxy Data: Data used in lieu of direct measurement; indicators; surrogate data.

Psychographic: Portrait of an individual in terms of personality traits, demographics, behavior patterns, and so on.

Qualitative: Having to do with essential characteristics or qualities not subject to quantitative measurement; distinguished from quantitative.

Quality of Life: An overall assessment of how pleasant, rewarding, or "good" one's life is, and vice versa.

Quantitative: Having to do with properties that can be determined by numerical measurement; distinguished from qualitative.

Quartile: Statistical term referring to one of four groups of equal frequency that make up a a distribution.

Queuing Theory: A probabilistic forecasting tool that provides statistical methods for estimating the inputs and handling of lines of customers, equipment, or material.

Rate Equation: The mathematical representation of change over time of a variable.

Regression Analysis: The numeric procedure of calculating the coefficients between two series of variables.

Relevance: The degree of pertinence; bearing upon the issue; applicability.

Reliability: Dependability, trustworthiness.

Rigor: A mathematical term meaning accuracy, exactitude.

Risk: The chance of damage, loss, or other unwanted event; often put in probabilistic terms.

Risk Analysis: A probabilistic forecasting method used in dealing with one-time-only operations. The Event Tree or the Fault Tree approaches are used in this method.

Scenario: An outline or portrait of a possible future; usually portrays unfolding events rather than being static in time.

Sensitivity Analysis: A technique in which is determined the relative importance of different factors in order to focus on the more crucial ones.

Simulation: A model; imitating a system or process in order to understand or predict its behavior.

Social: Pertaining to the society or group.

Social Indicators: Indirect measures of the well-being, growth, and so on of the society; proxy data.

Social Trends: Trends pertaining to the society as a system.

Society, Societal: A community of interrelated, interdependent individuals together comprising the social system.

Standard Deviation: A statistical measurement of variance from the mean, given in the original terms.

Subjective: Resulting from the preferences and customs of the individual; value-laden. Often contrasted with objective.

Surprise-Free: Describing a future that evolves from the present without discontinuities (i.e., surprises); used to describe "more-of-the-same" scenarios.

Survey Research: Research based on asking people questions.

Systems Analysis: The branch of science concerned with stating problems in systematic forms.

Technological: Having to do with technical change resulting from science, technology, and R&D.

Theory: A formulation of apparent relationships or underlying principles of observed phenomena.

Time Horizon: A specific date in the future.

Time Series: Historical data presented in uniform terms and covering a specified period of time.

Time Span: A specific period of time.

Trade-Off: The give-and-take involved in compromise or deal-making; the negatives that come along with the positives.

Transition Probability: The likelihood that a given event will be succeeded by another given event.

Trend: A general tendency or course of events.

Trend Extrapolation: A forecasting technique that involves extending time-series data in accordance with specified rules.

Values: The dominant mores of a person or society; the sum of an individual's preferences, needs, beliefs, priorities, motivations, and so on; in a society, those acts, customs, institutions, that are regarded in a particular way or how the group or individual estimates the worth of these. In mathematics, the quantities represented by the symbols in an equation.

Values Forecasting: A method involving clustering of values into a typology and forecasting change on the basis of broad scenarios or demographic shifts.

Values Studies: Analysis and/or forecasting the values of individuals or groups.

Variance: In statistics, the square of the standard deviation from the mean.

INDEX

INDEX

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